‘The Development of a Framework for Assessing the Integration of Construction Supply Chains’

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List of Abbreviations

BIM	Building Information Modelling
CSFs	Critical Success Factors
GB	Great Britain
IT	Information Technology
KPI	Key Performance Indicator
NEC	New Engineering Contract
NI	Northern Ireland
PRP	Performance Related Payments
RICS	Royal Institute of Chartered Surveyors
ROI	Republic of Ireland
SC	Supply Chain
SCM	Supply Chain Management
SPSS	Statistical Package for the Social Sciences
TQM	Total Quality Management
UK	United Kingdom

Acknowledgement

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ABSTRACT

Supply Chain Management (SCM) is increasingly becoming important in the construction industry, which is still largely a fragmented industry. Several government sponsored reports have been instrumental in promoting the concept in the UK construction industry. However, previous literature helped identify that construction organisations are in the need of a mechanism that would allow them to measure integration of supply chains. Hence this research aimed to develop a framework for construction organisations to assess and improve integration of their supply chains. In this endeavour a Delphi survey was conducted in the Northern Irish construction industry to 'build' a SCM framework, and thereafter a UK-wide questionnaire survey to test the framework.

Firstly, the Delphi method was used to prioritise and validate the inclusion of 13 critical success factors (CSFs) compiled from previous literature. This generated scores for each CSF, which could potentially be included in the developed SCM framework. Secondly, the Delphi method was used to develop the SCM framework based on the 13 CSFs and 4 levels of integration. This is the most significant contribution to knowledge created via this research.

Thereafter, an e-survey was undertaken to test the robustness of the SCM framework. This added rigour to this research and utilised a mixed methodologies approach. In addition to testing the propositions and receiving feedback on the SCM framework, the e-survey revealed the current and future levels of integration of construction supply chains in the UK. This is the first quantitative survey that has been conducted among individuals in the UK construction industry regarding integration of construction supply chains.

In conclusion, the proposed SCM framework is applicable to all main sectors of the construction industry; namely clients, consultants, main contractors, sub-contractors and suppliers. This empirically tested framework is easy to use and helpful in assessing and improving construction supply chains.

Note on Access to Contents

I confirm that the word count of this thesis is less than 100,000 words excluding the title page, contents, acknowledgements, summary or abstract, abbreviations, footnotes, diagrams, maps, illustrations, tables, appendices, and references or bibliography.

Chapter One

Introduction

Chapter 1 – Introduction

1.1 Background to research

The Latham (1994) and Egan (1998) reports on the UK construction industry highlighted problems in construction supply chains. It had been found that principles followed in the construction industry often worsen supply chain performance (Vrijhoef and Koskela, 1999). Egan (1998) proposed the integration of construction processes and products in the quest to deliver enhanced value to construction clients. This proposition necessitates the industry not to be segmented; instead it essentially requires all players of the construction industry to work in an integrated manner or as a 'unified team' (Briscoe and Dainty, 2005). Wolstenholme et al. (2009) report titled 'Never waste a good crisis' reinforced the need for collaboration in the construction industry, especially during times of economic downturn.

According to Vrijhoef and Koskela (1999), Muya et al. (1999) and Briscoe et al. (2001) the construction industry is far from addressing issues pertaining to integrated supply chains due to poor practices and attitudes. Cheng et al (2010) recognises that there is lack of trust in the construction industry. Richbell (2008) states that the construction industry is prone to conflict. Fearne and Fowler (2006) state that although some of these problems can be attributed to the project oriented nature of the industry, other project oriented industries such as the IT industry and automotive industry, have significantly improved their SC adopting practices from the manufacturing industries.

The construction industry has been struggling to achieve benefits realised in other industries so far (Cheng et al., 2010). The key objective of supply chain management (SCM) is to increase customer satisfaction by enhancing services such as stock availability and order cycle time (Cooper and Ellram, 1993), developing innovative solutions and synchronising the flow of products, services, and information to create unique, individualised sources of customer service value (Ross, 1998) and low cost and differentiated service to create a competitive advantage for the supply chain (Bowersox and Closs, 1996; Cooper and Ellram, 1993). Thus SCM is concerned with improving both efficiency and effectiveness in a strategic context to obtain competitiveness that ultimately brings profitability (Mentzer, 2001).

Mentzer (2001) explains that companies need to be provided with a mechanism which demonstrates stages of integration that will allow them to identify their current stage, and thereby improve. This is because companies are not achieving ‘true SCM’ despite many discussions of applying SCM practices. O’Brien (2002) and O’Brien et al. (2009) also supports the need for a framework that allows companies to understand and improve SCs, which can be generalised to the industry. He explains that since previous research is based on case studies, it makes it difficult to generalise. Therefore, a knowledge gap exists to develop a framework which describes stages of integration based on identified for companies to assess and improve themselves.

Several models for non-construction industries are available, such as from Stevens (1989), PRTM (2002), Lockamy and McCormack (2004), Hoffman and Reiner (2006), Vaidyanathan and Howell (2007) and McLaren (2006). These models have been produced within different contexts, and most of these models have been produced by practitioners or academics. However, due to the construction industry being somewhat unique compared to other industries, these models cannot be applied in a meaningful way to the construction industry. None of these models discuss the major problems in the construction industry, such as issues of trust, attitudinal problems or procurement methods which have an effect on the continuity of works in the construction industry. Hence such criteria need to be added to a framework that is developed, as identified earlier to describe stages of integration. Thus there appears a knowledge gap to create a framework encompassing such criteria in the construction industry, elaborated across a number of levels of integration.

Some models have been emerging for the construction industry somewhat recently (Sarshar et al., 1999; Love et al., 2004, Vaidyanathan and Howell, 2007). Sarshar et al. (1999) model was not applicable beyond an organisation, externally to SC members. Other models are not very descriptive with regard to issues in SCM in the construction industry, and do not highlight the aforementioned problems of trust, attitude or continuity of works in the construction industry or include stages of integration. Hence it is imperative and timely that a model for the assessment and improvement of construction SCs is developed for the UK construction industry.

1.2 Aim

This research aims to develop a framework to measure supply chain integration in the construction industry, and thereby encourage improvements in supply chains.

1.3 Objectives

The following objectives are derived from the aim of the research.

1. To systematically comprehend the application of principles of SCM in the construction industry.
2. To critically analyse SCM models available in literature for the construction industry (if available) and non-construction industries.
3. To develop a set of critical success factors (CSFs) that lead to SC integration in the construction industry.
4. To develop a framework that allows assessing and improving integration of construction SCs.
5. To test the framework with regard to its ability to assess and improve integration of construction SCs.
6. To evaluate the current and future levels of integration of construction SCs, conclude and make recommendations to the construction industry and academia with regard to integration of SCs in the UK.

1.4 Methodology

The following methodology would be deployed to reach aforementioned objectives. The methodology is presented diagrammatically in Figure 1.1. It is reproduced and further elaborated in chapter 4.

1. Carry out an extensive literature review on principles of SCM, applications of SCM in the construction industry and models available for assessing and improving SCs.
2. Compile a list of CSFs for integration of SCs, appropriate to the context of construction, based on previous literature.

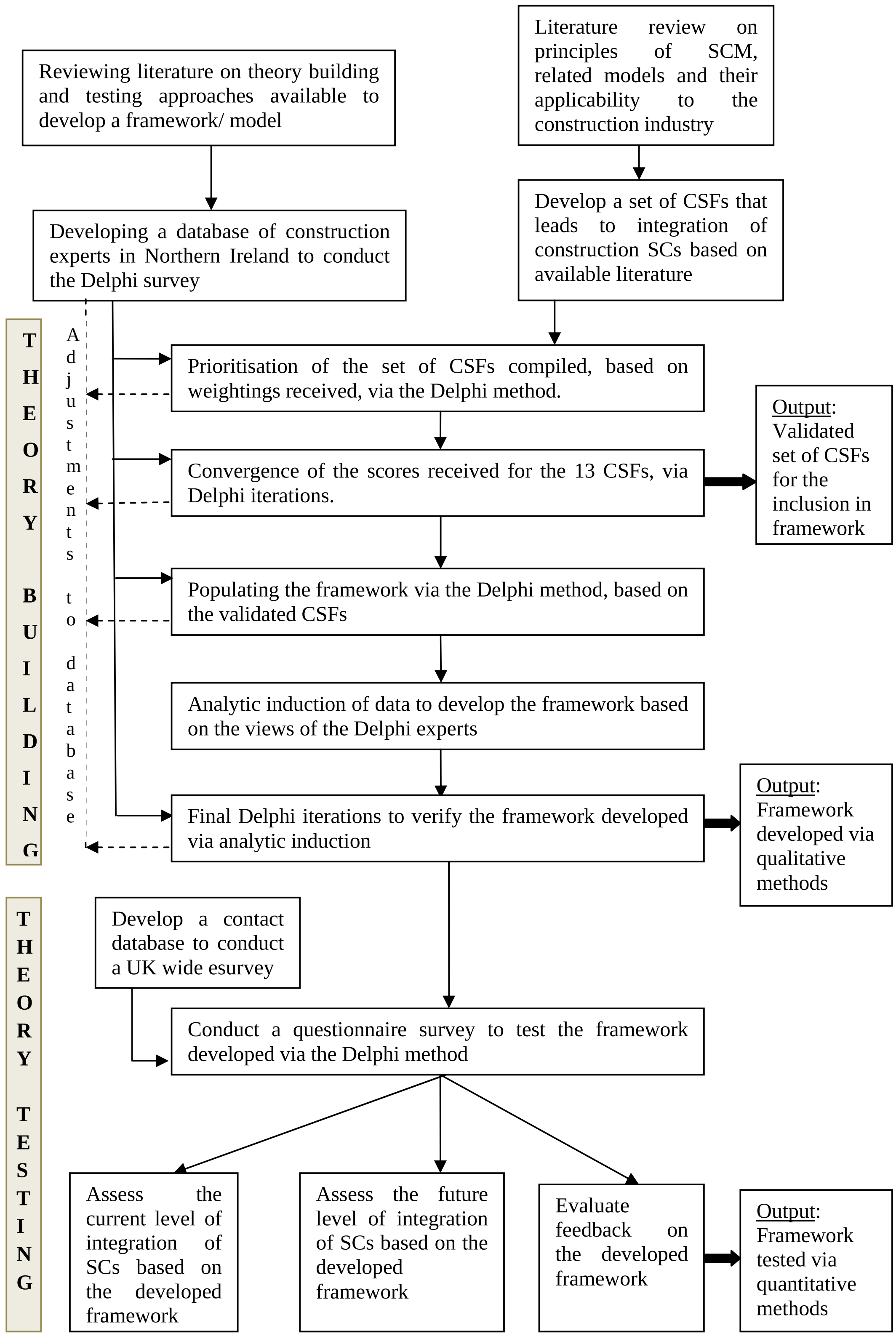

Figure 1.1 – Overview of the research methodology

3. Conduct a Delphi survey, among construction professionals in NI, to obtain scores for the CSFs which lead to integrated SCs in the construction industry, and check for comprehensiveness of the list of CSFs.
4. Conduct a Delphi survey, among the Delphi participants of the previous rounds, to populate each of the CSFs (prioritised and selected from previous Delphi rounds) across a number of levels of integration.
5. Analyse responses and produce a framework for SCM in the construction industry.
6. Test the framework with regard to its applicability, ease of use, ability to allow assessment of SCs, ability to allow improvement of SCs, etc. via a questionnaire survey conducted among construction professionals in the whole of UK.
7. Analyse the current level of integration of construction SCs in the UK.
8. Evaluate the anticipated level of integration of construction SCs in future, in the UK.
9. To conclude and make recommendations with regard to the use of the framework, level of integration of construction SCs, etc.

1.5 Scope

- The scope of this research will be limited to the UK construction industry, whilst Delphi studies for ‘theory building’ will be conducted in the construction industry of NI.
- A SC will be deemed to consist of 4 tiers for the purpose of this research; 1.Clients, 2.Consultants (Engineers, Architects, Quantity Surveyors and Project Managers), 3.Main contractors and 4.Suppliers (including sub-contractors, material and plant suppliers).
- The developed framework will be focusing the strategic level, and not the operational level of construction SCs.
- The framework will be aimed at the project level and organisational level within the construction industry.

1.6 Organisation of thesis

Chapter 1 – This chapter provides a background to the research, sets out the aim, objectives, scope and an overview of the methodology adopted for the accomplishment of the aim of this research.

Chapter 2 – This chapter reviews the principles of SCM, its evolvement, definitions, benefits, applications to the construction industry and the need for a framework to assess construction supply chains.

Chapter 3 – This chapter discusses various SCM models available in non-construction industries, and the limited number of models emerging for the construction industry in academic literature. The chapter explains the shortfalls of the available models when applying to the construction industry in the UK, and goes onto establish a list of CSFs (critical success factors) for the integration of construction supply chains.

Chapter 4 – This chapter justifies the research methodology adopted for this research. It discusses the survey types, ontology, epistemology and methodology of the research in general and justifies the specific research methods adopted to achieve the aim of this research.

Chapter 5 – This chapter explains how the Delphi survey was conducted to create a comprehensive list of CSFs and thereon to build a framework for the assessment and improvement of construction SCs. It explains the construction of questionnaires, selection of participants, pilot surveys, response rates, computation of scores for the CSFs and then moves on to discuss how each CSF was elaborated across 4 levels of integration. The chapter concludes with the developed SCM framework.

Chapter 6 – This chapter discusses the questionnaire survey and the analysis of the data collected via this method, in order to test the framework developed using the Delphi method. This survey assesses the current and future level of integration of construction SCs, and evaluates the feedback received for the developed framework.

Chapter 7 – This chapter compares and contrasts results from the different surveys and from previous literature to generate new findings, recommendations and contributions to knowledge of this research.

Chapter 8 – This chapter concludes all objectives set out in chapter 1, and lists the contribution to knowledge and key findings, recommendations to the construction industry, limitations of the research and recommendations for further research.

Chapter Two

Principles of supply chain management and their applications to the construction industry

Chapter 2 - Principles of supply chain management and their applications to the construction industry

2.1 Scope of chapter

This chapter gives an overview of supply chain management (SCM), SCM being the main research area of this study, within the context of the construction industry. The chapter initially explains the current interest in SCM within the construction industry. It then discusses the evolvement of SCM which is necessary to understand the various terms which are often discussed in conjunction with SCM. Discussion about other related concepts are then included. The chapter subsequently proceeds to discussing the application of SCM principles within the context of construction.

2.2 An overview of the construction industry and supply chain management

The construction industry has been struggling to adopt benefits of SCM, as claimed by the manufacturing industries for some time (Cheng et al., 2010). Government sponsored reports such as Latham (1994), Egan (1998), Egan (2002) and Wolstenholme et al. (2009) on the UK construction industry highlighted problems in construction supply chains. Egan (1998) proposed the integration of construction processes and products in the quest to deliver enhanced value to construction clients, and Wolstenhome (2009) further encouraged the concept during the economic downturn. Akintoye et al. (2000) state that the drive towards Public Private Partnerships (PPP) has also given better potential for SCM in the construction industry.

Although the above reports call for working as a unified team or in an integrated manner (Brisoe and Dainty, 2005), many researchers (Vrijhoef and Koskela, 1999; Richbell, 2008; Fearne and Folwer, 2006; Cheng et al., 2010) claim that the construction industry has many barriers to integrated SCs. Fearne and Fowler (2006) and Cheng et al. (2010) explain that the short-term, project oriented nature of the construction industry makes it difficult to embrace SCM. Fearne and Fowler (2006) describe the construction industry as ‘essentially a project based industry’ which operates in an uncertain, fragmented and complex environment. Figure 2.1 shows rich picture representation of a 'traditional supply chain' in the house building industry of low value fit out products. This diagram has left out the relationships between the consultants and the clients within a construction SC. However, some SCM models presented in chapter 2 will encompass these relationships as well.

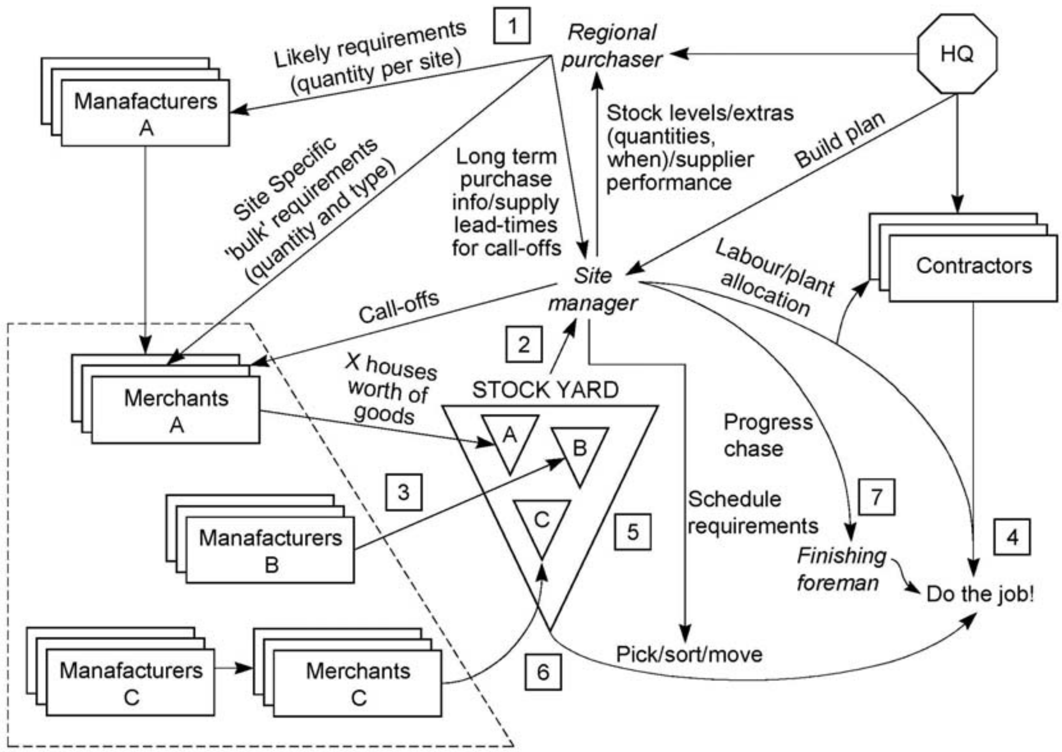

Figure 2.1 - Rich picture representation of a traditional construction supply chain (Naim & Barlow, 2003, p.597)

2.3 Collaborative forms of procurement and associated concepts in construction

Akintoye et al. (2000) state that government reports such as of Latham and Egan encouraged major reforms to procurement methods in the UK construction industry at the time in order to improve the practicality of SCM within the industry. Since different procurement methods are thought similar to SCM practices in the construction industry it is important to differentiate between these procurement methods in order to understand the similarities and dissimilarities of these methods with SCM practices.

There are many concepts that are related to or leads to good management of SCs in construction. Some of these concepts, such as lean construction or partnering, may have paved the way for the concept of collaboration or SCM in the construction industry. The subtle differences in some of these concepts are captured by Yeung et al. (2012), within the context of 'relational contracting' in Table 2.1. It can be observed that these methods share many commonalities with SCM such as cooperative relationships (with relational contracting), trust and collaborating beyond organisational boundaries (with partnering), pain and gain sharing (with alliancing), long-term collaboration to complement each other with skills and resources (with PPP) and joint decision making (with joint ventures). Similar to the discussions in section 2.5, which demonstrates that a number of different management techniques now fall within the parameters of SCM. It appears that the different approaches to procuring a construction project which has separately evolved over time can now be encompassed under the concept SCM. Researchers such as Green and May (2005) have observed that most definitions in collaborative theory are vague and ambiguous. However, Fawcett and Magnan (2002) assert that the concepts such as SCM, lean and partnering are used synonymously with collaborative forms of procurement, quite frequently, in non-construction industries as well (Tennant and Fernine, 2012).

2.3.1 Relational contracting, partnering and alliancing in construction

The definitions captured by Yeung, Chan and Chan (2012) to emphasize the subtle differences between some forms of procurement are listed in the table below.

Table 2.1 - Collaborative forms of procurement in the construction industry (adopted from Yeung, Chan and Chan, 2012)

Type of relationship between organisations	**Definition**
Relational contracting (RC)	Based on recognition of mutual benefits and win-win scenarios through more cooperative relationship between parties. RC embraces and underpins different approaches, encompassing partnering, alliancing, joint venture and other

Type of relationship between organisations	**Definition**
	collaborative working arrangements and better risk sharing mechanisms. (Macniel 1978; Alsagoff and McDermott 1994; Jones 2000; Rowlinson and Cheung, 2004; Rahman and Kumaraswamy 2002, 2004; Palaneeswaran et al. 2003; Kumaraswamy et al. 2005; Ling et al. 2006; Rahman et al. 2007).
Project partnering	A long-term commitment between two or more organisations for the purpose of achieving specific business objectives by maximising the effectiveness of each participant's resources. This requires changing traditional relationships to a shared culture without regard to organisational boundaries. The relationship is based on trust, dedication to common goals, and an understanding of each other's individual expectations and values (Construction Industry Institute, 1991).
Strategic partnering	The major difference between project partnering relationships established for a single project) and strategic partnering (a long-term commitment beyond a discrete project) is that the former is for a single project (Construction Industry Institute, 1991) but the latter involves at least two projects (Bennett and Jayes, 1998).
Project alliancing	A cooperative arrangement between two or more organisations that forms part of their overall strategy, and contribute to achieving their major goals and objectives for a particular project (Kwok and Hampson, 1996). With alliancing, there is a "joint" rather than "shared" commitment. Parties agree on their contribution levels and required profit beforehand and then place these at risk. If one party in the alliance under-performs, then all other alliance partners are at risk of losing their rewards (profit and incentives) and could

Type of relationship between organisations	Definition
	even share losses according to the agreed project pain-sharing/gain-sharing model (Walker et al., 2000 & 2002).
Strategic alliancing	The major difference between project alliancing and strategic alliancing is that project alliancing has a defined end, which is most commonly the practical completion date of a project (Peters et al., 2001). However, a strategic alliance usually exists between two companies that extend beyond a specific project (Walker et al., 2000).
Public Private Partnerships (PPP)	The collaborations where the public and private sectors both bring their complementary skills to a project, with different levels of involvement and responsibility, for the sake of providing public services (Hong Kong Efficiency Unit, 2003).
Joint venture	Joint Ventures involve two or more legally distinct organisations (the parents), each of which shares in the decision-making activities of the jointly owned entity (Geringer, 1988).

Yeung et al. (2012) claim that definitions for the concept 'relational contracting' varies significantly in literature and that they are quite vague, probably because the concept is still developing. Hence they use the Sunflower Model (Figure 2.2) to explain the concept 'relational contracting. It demonstrates five relationship-based core elements identified, including: (1) commitment; (2) trust; (3) cooperation and communication; (4) common goals and objective; and (5) win-win philosophy. Apart from the five core elements, there are seven petals, including: (1) continuous improvements; (2) agreed problem resolution methods; (3) formal contract; (4) real gain-share/pain-share; (5) a joint declaration; (6) equity; and (7) facilitated workshops. Therefore relational contracting can be observed as a concept that focuses on the human aspect and softer side of SCM, whilst leaving out SCM issues such as supplier delivery management, method of procurement or IT infrastructure. Yeung et al (2012) states that relational contracting can lead to sustainable supply chains. Rowlinson and Ki (2011) also say that relational approaches create a collaborative and cooperative working environment, where trust can be developed, which leads to a sustainable supply chain.

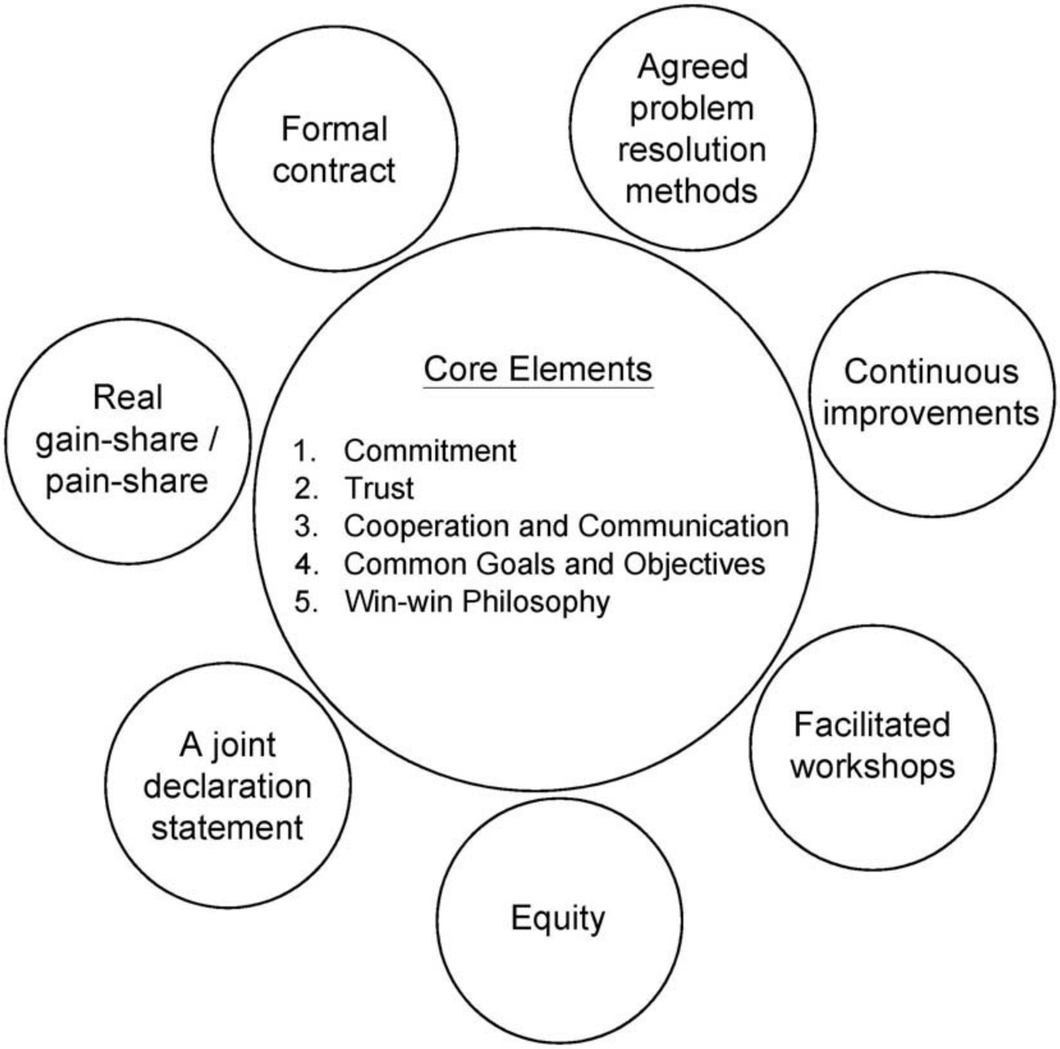

Figure 2.2 - Sunflower model containing the key elements of relational contracting (adapted from Nyström, 2005; Yeung et al., 2007; cited in Yeung et al., 2012).

It should be noted that Nyström (2005) and Yeung et al. (2007) presents similar elements for partnering and alliancing in the construction industry. Nyström (2005) asserts that trust and mutual understanding are the two core components of partnering and that (1) economic incentive contracts; (2) relationship building activities; (3) continuous and structured meetings; (4) facilitator; (5) choosing working partners; (6) predetermined dispute resolution method; and (7) openness are the seven elements, similar to petals in the model above. Then Yeung et al (2007) describe alliance in construction as having three core elements: namely, trust, long-term commitment, and cooperation and communication, and another nine elements encircling: (1) win-win philosophy; (2) equity; (3) agreed problem resolution methods; (4) common goals and objectives; (5) continuous improvements; (6) alliancing workshops; (7) early selection of contractors; (8) for a single project only; and (9) for at least two projects (Yeung et al., 2012). Thus it appears that similar to relational contracting, discussed previously, partnering and alliancing encompass a number of ‘soft’ issues of SCM. It can also be observed that partnering and alliancing, unlike the concept SCM, does not deal with issues at the operational level such as availability of material on site or IT facilities such as BIM.

Despite the list of definitions of the concepts discussed in Table 2.1, these concepts are discussed synonymously with each other quite often (Green and May, 2005; Fawcett and Magnan, 2002; Tennant and Fernie, 2012). Moreover, there are a few more terminologies that are discussed in close relation to SCM in construction. This is due to the similarities these concepts share with SCM as explained above.

2.3.2 Relationship management

Another theory that is closely related to ‘relational contracting’ is ‘relationship management’. The concept ‘relationship management’ promotes collaborative environments and frameworks for all participants to engage in the supply chain (Cheung, 2006). Thus relationship management is one mechanism that can improve the management of SCs. According to Rowlinson and Ki (2011) relational contracting is an approach for a fixed duration with opportunities for future contracting, whilst relationship management is a business strategy which provides a framework for all participants to engage with the supply chain. The most widely adopted definition for relationship management is ‘attracting, maintaining and – in multiservice organisations – enhancing customer relationships’ (Berry, 1983, p.25; cited in Rowlinson and Ki, 2011).

2.3.3 Framework agreements

'Framework agreements' is a form of procurement that was gaining popularity during the latter years of the last decade (Tennant and Fernie, 2012) with 2.9% of contracts, by value, being procured via framework agreements (RICS, 2010). A framework agreement is defined as "An agreement between one or more contracting authorities and one or more economic operators, the purpose of which is to establish the terms governing contracts to be awarded during a given period, in particular with regard to price, and where appropriate, the quality envisaged" (The Official Journal of the European Union, 2004). "In other words, the framework agreement is a generic expression used for buyer–supplier coalitions trading under pre-specified conditions of engagement (Constructing Excellence, 2005; cited in Tennant and Fernie, 2012). Hence one could argue that 'framework agreements' have facilitated the ability of construction organisations to create SCs, by setting a framework for a substantial number of years. Yet it has been observed over the last few years, since recession, that organisations are moving away from collaborative working and are displaying cost-cutting behaviour (Tennant and Fernie, 2012). For example, BAA terminated their framework agreements in 2009 and retail clients are supporting traditional competitive tendering methods (Gardiner, 2010). However, Blake et al. (2003) claims that this phenomenon is observed in other industries as well during periods of economic hardships.

2.3.4 Programme management

Shehu and Akintoye (2009, p.704) defines programme management, after an extensive literature review, as an 'integrated, structured-framework that co-ordinates, aligns and allocates resources, and plans, executes and manages a number of related construction projects to achieve optimum benefits that cannot be realised if the projects are managed separately'. Since a 'framework agreement' provides for an environment where construction project participants can get involved in multiple projects (Gruneberg and Hughes, 2004), framework agreements, programme management and SCM can be understood as synonymous by some construction professionals. However, it should be understood that programme management is a management concept, whilst framework agreements are regulatory and can promote integration of SCs.

2.3.5 Prime contracting

Pryke (2006) describes prime contracting as a ‘public sector procurement approach involved in the introduction of the role of a cluster leader combining the skills and knowledge traditionally provided by the architect, the chartered quantity surveyor, and the construction manager’. The two most common alternatives in prime contracting are single prime and multiple prime methods. According to Holland (2002) and Monti (1997) single prime contracts are more favoured due to cost and quality, as it is claimed that multiple prime contracts have higher bid costs, more claims and poor quality, etc. A multiple prime contract is where the public sector organisation set up contracts with a general contractor and speciality contractors via competitive bids, whilst a single prime contract involves the public sector organisation appointing one general contractor, who in turn will establish relationships with specialist subcontractors (Rojas, 2008). Therefore prime contracting, similar to framework agreements, is another approach which can potentially make application of SCM principles more realistic in the construction industry.

2.4 What is supply chain management?

Many definitions have been produced for SCM since the 1990’s for different industries. These definitions are equally applicable in the construction industry despite claims that the construction industry is unique compared to other industries. Underlying many of these definitions is the assumption that developing understanding relationships within and between organisations underpins an ability to optimise ‘flows’; break down process discontinuities; develop networks; make decisions about managing competencies and; optimise the use of power (Fernie and Thorpe, 2007). These assumptions can be considered relevant across any organisation; hence are applicable to the construction industry.

2.4.1 Definitions of supply chain management

A definition produced for the retail and manufacturing sector by Johnston (1995) defines SCM as ‘the process of strategically managing the movement and storage of materials, parts and finished inventory from suppliers, through the firm to customers'. Movement and storage of materials is an important aspect in construction SCs. Naim and Barlow (2003) has analysed this aspect of SCs in their research of the house building industry and depicted the interactions as shown in Figure 2.1. However, Johnston's (1995) definition only captures the inventory aspect of SCM and leaves out aspects such as purchasing of material or selection of suppliers.

Kranz (1996) explains SCM more loosely as 'the effort involved in producing and delivering a final product from a supplier's supplier to customer's customer. Fundamentally, SCM aims to increase the transparency and alignment of a supply chain's coordination and configuration, regardless of functional or organisational boundaries (Cooper and Ellram, 1993).

A more recent and comprehensive definition for SCM produced by Lambert and Cooper (2000, p.66) reads as follows:

> "Supply chain management is the integration of key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders."

Lambert and Cooper's definition is a broad and generic definition, and is applicable to the construction industry. For example, the integration of the design and construction processes can result in a buildable, cost effective and unique building resulting in excellent client satisfaction and increased profits for the consultants and contractors. Another example is the integration of material suppliers and contractors which results in materials being delivered more effectively and efficiently, which in turn results in lower storage costs, tailor-made materials, etc. benefiting the client, contractor and the supplier via reduced costs and quality products.

In summary SCM recognises interdependency in the supply chain and seeks to improve its configuration and control base by integrating inter and intra organisational business processes (Love et al., 2004). Moreover it is interesting to note how supply chain integration is seen as the method of managing supply chains. Hence many refer to SCM and supply chain integration synonymously.

2.4.2 Supply chain drivers

Hugos (2006) states that there are five major supply chain drivers; Production; Inventory; Transportation; Location and Information. The integration of all these drivers should provide the optimum supply chain. Figure 2.3 demonstrates the linkages of each of these drivers. One can easily note that the central driver is 'Information' and is a vital component to SCM. Information is the basis on which decisions are made in order to achieve supply chain integration.

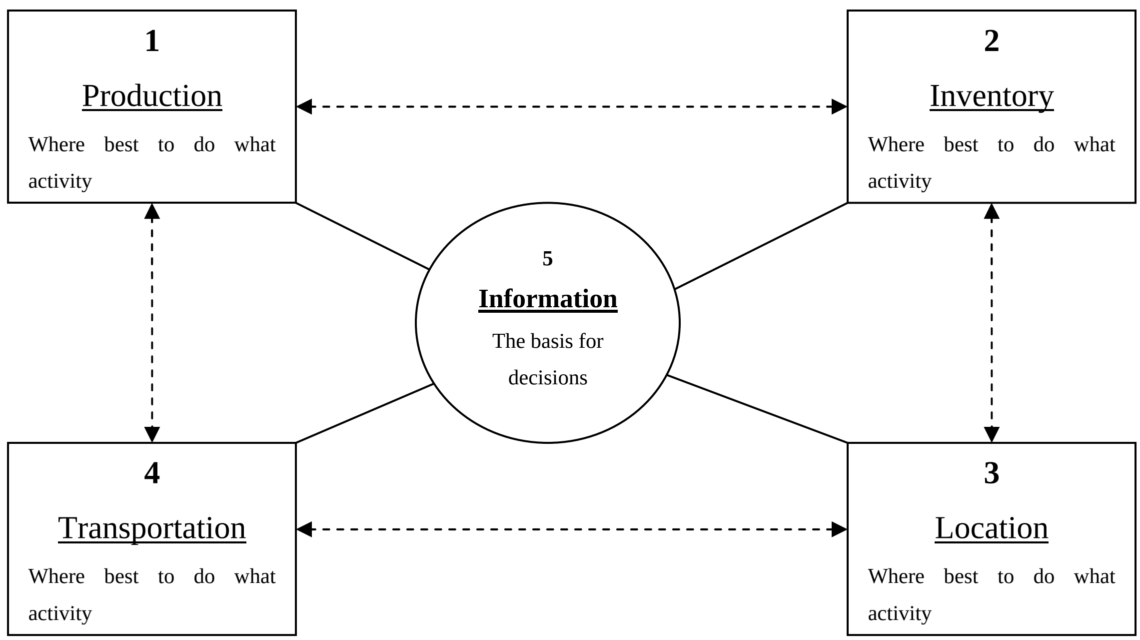

Figure 2.3 - The five major supply chain drivers (Hugos, 2006, p.17)

Hugos (2006) explains that the 'right combination of responsiveness and efficiency' in each of these drivers will allow a supply chain to increase production whilst simultaneously reducing operational costs. For example a supply chain can increase production and reduce operational costs by tackling the 'bullwhip effect' and introducing just in time (JIT) systems. This will require the 'right combination of responsiveness and efficiency' in the Inventory and Transportation drivers. The devising of the right combination will depend on the Information available on demand or in other words the needs of the customer. After all, according to Cooper and Ellram (1993), a key objective of SCM is to increases customer satisfaction

The bullwhip effect is a well known phenomenon of disintegrated or traditional supply chain inefficiencies. This phenomenon shows how a small change in product demand by the consumer at the front end of the supply chain translates into larger and larger inventories with huge safety stocks at the rear end of the supply chain (Hugos, 2006). This is due to poor communication and coordination, which leads to SC members holding unnecessarily high levels of stock for potential high demand situations of customers. This can simply be avoided by sharing more information about stock levels up and down the SC. Therefore, most SCM research in the past decades in the manufacturing industries has focused on the bullwhip effect, in order to eliminate or minimise inefficiencies and generate cost savings.

2.4.3 Benefits of supply chain management

Following are benefits that can be expected from integrated supply chains within and across organisations of diverse industries according to previous research. Many of these benefits are intertwined and dependent on effective and efficient flow of information. For example, within the context of the construction industry, a design consultant can produce the most customer-tailored and buildable drawings if there is access to the necessary information from clients and contractors, which will lead to increased customer satisfaction and reduced costs (due to less rework). Such effective integration can also lead to innovative solutions to clients' problems and also allow the consultants to become much more responsive to clients' needs. This will also let the consultants create a competitive advantage over its competitors.

1. Increased customer satisfaction (Cooper and Ellram, 1993; Anderson and Lee, 1999; Mentzer et al., 2000)
2. Competitive advantage (Kalakota and Robinson, 1999; Bowersox and Closs, 1996; Cooper and Ellram, 1993)

3. Increased responsiveness (Chopra and Meindl, 2001; Dagenais and Gautschi, 2002; Lee, 2000)
4. Reduced operational costs (Kalakota and Robinson,1999; Hugos, 2006; Chopra and Meindl, 2001; Dagenais and Gautschi, 2002; Lee, 2000)
5. Synchronized flow of products (Kalakota and Robinson, 1999; Ross, 1998; Fernie and Thorpe, 2007)
6. Better coordination among supply chain members (Kalakota and Robinson, 1999; Fernie and Thorpe, 2007)
7. Enhanced stock availability and order cycle time (Cooper and Ellram, 1993; Anderson and Lee, 1999; Mentzer et al., 2000; Lee et al., 1997)
8. Innovative solutions (Ross, 1998)
9. Access to information to create unique customer service value (Ross, 1998)

Whilst the first three benefits mentioned above refer to benefits at the strategic level, the rest are benefits at an operational level. It becomes possible for organisations to achieve the benefits at the strategic level due to benefits arising at the operational level. These benefits at the operational level can all be attributed to the five major supply chain drivers explained by Hugos (2006; refer Figure 2.3). Hugos (2006) had demonstrated that Information is the vital driver and remains central to all drivers. Thus the key benefit of adopting SCM is the access to information which would not have been possible without integration. It should be noted that characteristics of useful information such as reliability, timeliness, relevance, completeness, etc. can be achieved easily and consistently within an integrated supply chain.

2.5 Related concepts and evolvement of supply chain management

2.5.1 Porter's value chain

'Before processes can be managed effectively up and down the supply chain, they must be managed well inside the focal firm. Within any company, a variety of functions have responsibility for making decisions that will determine how much value is created.

Michael Porter (1985) coined the term value chain to describe the interconnected nature of these internal functions' (Fawcett et al., 2007).

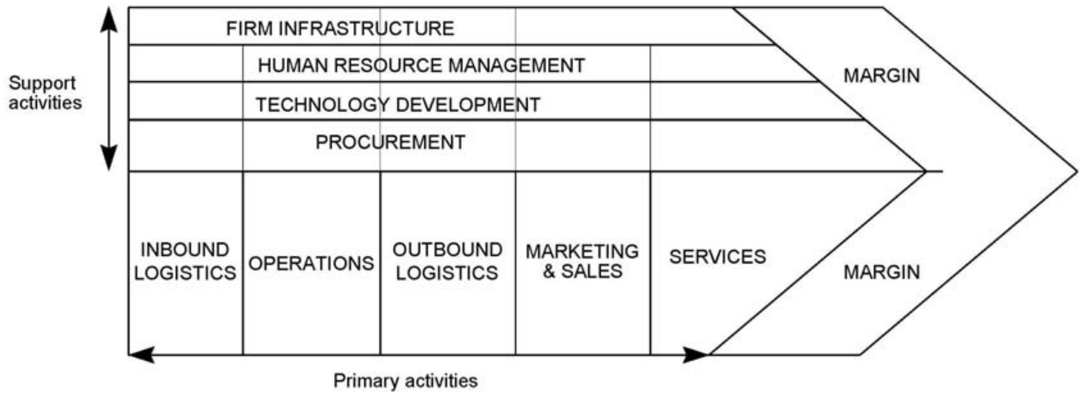

Figure 2.4 - Porter's value chain

In 1985 Michael Porter suggested a model (shown in Fig. 2.4) which encapsulates generic functions of an organisation. These were mainly divided into two categories as Primary activities and Secondary activities. Primary activities are explained as a chain consisting of Inbound logistics, Operations, Outbound logistics, Marketing and sales, and Services. Porter explains that each of these primary activities add a certain value to the product in concern which allows the organisation to generate a profit when selling the product and maintain a competitive advantage. Porter (1985) also reminds about the importance of secondary activities in the process of adding value to products. He classifies the secondary activities within an organisation as Procurement, Technology development, Human resource management and Firm infrastructure.

Possibilities of forward and backward integration with external firms in order to increase profit margin was also suggested by Porter (1985) in his book 'Competitive Advantage'. Porter identified integration as a 'driver of uniqueness'. Vertical integration was also identified as a cost driver by Porter. He explained that integration can reduce costs of a value chain in several ways. Vertical integration with external firms essentially meant owning of value chains of several organisations.

Aforementioned suggests that the current concept of supply chain integration has been in existence since 1985. However one should bear in mind that integration of value chains explained by Porter (1985) essentially meant owing the value chains of several organisations, although the model mainly focused on a single organisation. Today we expect integration to be across several organisations as can be seen from the following definition produced by the Institute of Supply Chain Management. ‘SCM is the design and management of seamless, value added processes across organisational boundaries to meet the real needs of the end customer’ (Fawcett et al., 2007, p.8).

2.5.2 Just-in-time systems

According to Svensson (2001) just-in-time (JIT) systems are conceptually similar to SCM. Ballou (1992, p.153) explains JIT as ‘a philosophy of scheduling wherein the entire supply channel is synchronised to respond to the requirements of operations or customer’.

JIT is a concept developed by the Japanese who created the Toyota Production System. The ultimate objective of JIT production is to supply the right materials at the right time and in the right amount at every step in the process (Tommelein and En Yi Li, 1999). ‘It is based upon the simple idea that wherever possible no activity should take place in a system until there is a demand for it. Thus no products should be made, no components ordered, until there is a downstream requirement’ (Christopher, 1992, p.153).

According to Toyoda (1987) JIT signifies a continuous search for waste reduction and to make only what is needed ‘just in time’ (Svensson, 2001). Car manufacturers have been striving to reduce, and in some cases eliminate inventories, reducing the number of subcontractors used and the sharing or diffusion of manufacturing, assembling, research and development of new materials and components (Svensson, 2001). This suggests the need for reliable, preferably long term relationships with selected suppliers. Hence it can be concluded that SCM is required to derive the maximum benefits of JIT systems.

Kannan and Tan (2005) concluded based on their study that JIT, Total Quality Management (TQM) and SCM have linkages both at strategic and operational levels.

TQM is a philosophy which promotes long range thinking, reducing rework, team based problem solving and continuous improvement amidst other practices (Ross, 1993). Kannan and Tan (2005) state that all three concepts contribute towards improving performance.

2.5.3 Build to order supply chain (BOSC)

Driven by global competition and the continuing expansion of knowledge, firms are organising Build to Order Supply Chains (BOSC) that seek to competitively orient an entire supply chain towards providing near-instant delivery of customised products and services on a mass-scale. There are two key elements inherent in a BOSC: downstream-oriented build-to-order (BTO) strategy and upstream-oriented just-in-time (JIT) strategy. Inherent in BOSC strategy is the need to integrate the entire supply chain from upstream suppliers through downstream orders and delivery processes (Christensen et al., 2005).

2.5.4 Lean production

The concept of ‘lean production’ or ‘lean manufacturing’ also stemmed from the Toyota Production System. The term ‘lean production’ was coined by Womack et al. (1990) in their book ‘The machine that changed the world’. The goal of lean production was to develop a value chain ensuring elimination of all waste, including wastage of time (Naylor et al., 1999). Put simply lean means production without waste. Womack et al. (1990) explained that lean manufacturing is much more than a technique; it is a way of thinking, and the whole system approach that creates a culture in which everyone in the organisation continuously improve operations (Taj and Berro, 2006).

The lean approach is focused on systematically reducing waste in the value stream. The waste concept includes all possible defective work/activities, not only defective products. Waste can be classified in eight categories (Taj and Berro, 2006):

1. *Motion*: movement of people that does not add value.
2. *Waiting*: idle time created when material, information, people or equipment is not ready.

3. *Correction*: work that contains defects, errors, rework mistakes or lacks something necessary.
4. *Over-processing*: effort that adds no value from the customer's viewpoint.
5. *Over-production*: producing more than the customer needs right now.
6. *Transportation*: movement of product that does not add value.
7. *Inventory*: more materials, parts or products on hand than the customer needs.
8. *Knowledge*: people doing the work are not confident about the best way to perform tasks.

Whilst Taj and Berro (2006) discusses lean principles within the context of a value chain within one organisation, Naylor et al. (1999) sees the principles within the context of supply chains. They state that principles of lean production can be applied to inventory and SCM to reduce inventories and system performance.

Thus it can be concluded that JIT systems function within a system of lean production. Furthermore it suggests that benefits of lean production can be optimised by applying lean principles within the entire supply chain rather than focusing on one organisation.

2.5.5 Agile production

Agile production or agile manufacturing is another popular concept and is often discussed within the context of supply chains. Agility was originally defined as ‘a continual readiness to change, sometimes to change radically’ (Goldman et al., 1995). Naylor et al. (1999) explains agility as the ability of using market knowledge and a virtual corporation to exploit opportunities in a volatile market. It should be noted that agile manufacturing essentially requires a responsive supply chain (Kidd, 1995). Thus agile production is similar to a supply chain combination skewed towards responsiveness than efficiency.

Some authors observe lean and agile paradigms in isolation and some are of the view that all organisations which were previously striving to become lean should now focus on being agile. This is too simplistic a view. Although lean and agile paradigms are distinctly different, it is possible to have a combination of these within a single supply chain (Naylor et al., 1999).

2.5.6 Leagility

The adoption of a combination of both lean and agile productions is now commonly referred to as 'leagility'. According to Naylor et al. (1999) the ideal combination or the leagility of a supply chain will depend on the needs of the customers and the location of its supply chain members. The authors explain that within a specific market sector the need for higher levels of service and quality or lower costs and shorter lead times will arise and the metrics will be gauged in different ways. Whilst Naylor et al. (1999) only identifies location and customer needs as factors determining the leagility of a supply chain Hugos (2006) identifies five factors. Hugos (2006) identifies 'Location' as one of these factors. The other four factors are Production, Inventory, Transportation and Information. Hence it can be concluded that leagility of a supply chain should depend on customer needs and on each of the five supply chain drivers as demonstrated in Figure 2.3.

2.5.7 Lean construction

Implementation of lean construction should be done in three stages according to Green and May (2005), where stage 1 deals with waste elimination from a 'technical and operational perspective', stage 2 deals with team working among SC members and eliminating adversarial relationships and stage 3 deals with 'structural change of project governance' encompassing joint IT tools, prefabrication, concurrent engineering, long-term contracts, etc. Eriksson (2010) also presents a broad range of core elements of lean construction; namely (1) waste reduction, (2) process focus in production planning and control, (3) end customer focus, (4) continuous improvements, (5) cooperative relationships and (6) systems perspective.

The most important core element remains waste reduction (Green, 1999; Ballard and Howell, 2003; Jorgensen and Emmitt, 2008; Mao and Zhang, 2008), the main reason for the evolvement of the concept of lean construction. There are a number of aspects that lead to waste reduction according to Eriksson (2010). (1) Housekeeping – keeping a well organised and tidy site is crucial to waste reduction (Ballard *et al.* , 2003; Salem *et al.*, 2006); (2) A JIT system which ensures efficient transportation and stockholding (Fearne and Fowler, 2006; Jorgensen and Emmitt, 2008; Mao and Zhang, 2008); (3) IT systems, such as 3D modeling that allows correction prior to execution of activities (Ballard *et al.* , 2003; Green and May, 2005); (4) Joint IT tools that facilitate SC integration, and thereby cost and schedule success (O'Connor and Yang, 2004; Woksepp and Olofsson,2008); (5) Prefabrication, which allows components to be manufactured off-site leading to increased quality, reduced waste, reduced overall construction time, etc (Green and May, 2005).

Supply chain integration has become an integral part of lean construction in the recent years. As discussed above, integrated supply chains can lead to waste reduction, etc. Hence it would be fair to say that lean construction ethos has increased the awareness and application of integration of supply chains.

2.6 Application of supply chain management in construction

There are a number of substantial contributions within the SCM literature that make explicit and implicit reference to the importance of context in generating theory and understanding the practice of SCM (Mouristen et al., 2003; Cox et al., 2002). Notably, Porter’s (1985) five forces relate to institutional structures and contextual factors that cannot be presumed to be consistent across industries (Fernie and Thorpe, 2007).

SCM is a concept which is extensively advocated and promoted throughout the construction sector via many initiatives and networks. SCM is assumed by some organisations to be highly relevant to the construction sector and remains central to arguments for efficiency gains (Fernie and Thorpe, 2007). The use of innovative managerial concepts is argued to make particular projects in the construction sector higher performers (Fernie et al., 2006). Moreover Egan (1998) advocated the integration of construction processes and products in order to enhance value delivered to construction clients. Thereafter, a survey conducted among the top 100 contractors in the UK has revealed that 90% of these contractors considered SCM important for their organisation

(Akintoye et al., 2000). Therefore it becomes necessary to develop an SCM framework to help such organisations assess and improve their SCs.

2.6.1 Criticisms of SCM practices in construction industry

Although Latham (1994), Egan (1998), Egan (2002) and Wolstenhome (2009) encouraged integration of SCs in the construction industry, Vrijhoef and Koskela (1999) claim that the construction industry is far from addressing issues pertaining to integrated supply chains. A survey carried out by Muya et al. (1999) has revealed that although there is commendable coordination between construction contractors and suppliers, there is evidence of main contractors changing suppliers frequently, making late payments, not sharing strategic information and offering poor feedback to these suppliers. This finding is confirmed by a study conducted by Briscoe et al. (2001) which revealed considerable amount of attitudinal problems between construction contractors and suppliers, and Cheng et al. (2010) who states that, therefore, the industry has issues of trust.

Hence some authors such as Fernie and Thorpe (2007) argue that it does not make sense for construction organisations to implement and sustain integrated supply chains in the sector. These various arguments suggest that implementation of SCM in the construction industry, and its potential benefits would be different to most other industries. Thus it is important that SCM principles are implemented in a manner that is applicable to the construction industry. Cheng et al. (2010) and Fearne and Fowler (2006) recognise aforementioned problems in the construction industry and attribute them to the nature of the construction industry. The short-term project orientation within an uncertain environment does not induce trust (Chen et al., 2010) and makes it difficult to invest in resources for integration of SCs due to the short payback periods involved. Hence there may be a limit beyond which integration of SCs is not viable for short term construction projects. Yet, if the construction industry can innovate with regard to creating long-term relationships, within a project-oriented industry, it may be possible to overcome these barriers.

Naim and Barlow (2000) have identified that common problems in the construction industry such as lack of visibility of long term market requirements, poor transfer of information along the SC, dissatisfied clients, poor management of deliveries of suppliers, poor availability of subcontractors and materials on site can be rectified via good management of SCs. Some of these problems that they have identified in the construction industry are, when reversed, what is identified as benefits occurring from SCM in other industries (refer section 2.4.3). Hence it is timely that the construction industry embraces SCM ethos to enjoy the benefits discussed in section 2.4.3, similar to other industries.

2.7 The need to measure supply chain integration

Mentzer (2001) states that although much is being said about SCM, few companies are achieving true SCM. Thus he explains that it would be worthwhile to explore the true extent of SCM in companies, stages of SCM sophistication and how companies can identify in which stage they are located, and how to move to higher stages. However it must be noted that overly focused customisation of a supply chain would ruin its efficiency whilst a highly integrated supply chain may reduce its flexibility. Zailani and Rajagopal (2005) state that 'there needs to be a balance between good customer satisfaction and supply chain efficiency'. Hence it can be inferred that there is a limit to which construction supply chains should be integrated, to ensure the proper balance between efficiency and effectiveness.

O'Brien (2002) states that although many case studies on SCM have been carried out, there has not yet been developed 'a set of standard tools, models, and representations that allow us to generally describe, analyse, and prescribe improvements to a given construction supply chain, in particular the development of a reference model'. He further states that 'there is no framework or theory to fully relate focused improvements to overall supply chain performance or to design an overall supply chain structure'. This supports the suggestion of Mentzer (2001) to develop stages of sophistication of supply chains. According to O'Brien et al. (2002) most previous research carried out on SCM focus on projects instead of organisations, industries or markets. This has led to results being project specific, thus disallowing generalisation of results. Hence it is important that SCM models are produced with a focus larger than a project. It must also be realised that to promote SCM in the long-term, the concept has to be embraced at the organisational level, rather than the project level. Thus, it is more appropriate to generate a SCM framework which focuses on the construction organisation, than at the construction project level.

The development of a framework will provide construction organisations a snapshot of factors which need to be managed in order to improve their SCs, from one stage to the next. For example, as communication or information transfer was identified as problematic in the previous section, if included as a criterion in the framework, it will firstly inform the construction organisations of the need for communication for good SCM; secondly, the descriptions will help organisations understand if they are doing well or not based on stages of the framework with regard to the criterion; and lastly it will help organisations understand the next stage to which they can move to. Thus such a framework would contribute to knowledge in the area of construction SCM.

2.8 Summary of chapter

Based on literature presented in this chapter it can be concluded that SCM is about establishing networks which will allow a smooth flow of information, which will in turn enable supply chain partners to make informed decisions. The level of integration of a supply chain depends on quality, quantity and timeliness of information. The ability or enthusiasm to transfer information would depend on structure and culture of organisations, IT infrastructure, training of personnel involved, etc. Information could help decision making at the strategic or operational level of supply chains. It is the responsibility of the supply chain members to decide the leagility or the right combination of efficiency and responsiveness of the supply chain based on available information. It was established that SCM is considered important by construction organisations and is promoted by the government in the UK. Many problems experienced in the construction industry can be resolved with SCM and the industry can start experiencing similar benefits as other industries. Thus it was recognised that a framework could help resolve these problems, and enjoy more benefits of SCM. Thus the development of a framework could significantly contribute to knowledge. It was acknowledged that there is a need to measure integration of construction SCs, and that it is more appropriate for this to be from an organisational perspective, rather than a project perspective. Hence the purpose of this research, which is to develop a mechanism to assess the integration of construction SCs, was established.

Chapter Three

Measuring supply chain integration in the construction industry

Chapter 3 - Measuring supply chain integration in the construction industry

3.1 Scope of chapter

The previous chapter discussed the principles of SCM, its importance to the construction industry, the call for supply chain integration in many industries including the construction industry and the need to measure the degree of integration. This chapter discusses various types of models and frameworks that are available for supply chain integration in various industries and some conceptual frameworks that had been suggested for the construction industry in more recent times. It also identifies a knowledge gap, which proposes the need for a construction-specific framework from an organisational perspective in the UK and CSFs (critical success factors) that should be included in a construction SCM framework.

3.2 Non-construction specific models available for assessing supply chains

With concepts such as JIT and TQM, manufacturing organisations started focusing on improving lead times, reducing the bull whip effect, improving stock control, reducing wastage and improving quality. Most of the issues were arising at the operational level, and were dealt with at this level. However, over time it becomes apparent that these issues can be managed with soft management techniques practiced at the strategic level. It became clear that management of the SCs could lead to, or in some cases be synonymous with concepts such as TQM and JIT, within limited parameters. With the acknowledgement of the need to manage SCs, the emergence of models which describe the different levels of integration of organisations (e.g.- Stevens, 1989; PRTM, 2002; Hoffman and Reiner, 2006) appeared in literature. These generic models are discussed in this section, as the aim of this research is to develop a model for the construction industry similar to these as identified in chapter 1 and 2. This section also presents models which are not presented using stages of integration (e.g.- Chen & Paulraj, 2004; Love et al., 2004) to demonstrate the breadth of models available in literature. These models also indicate critical success factors in promoting SCM, which can be incorporated to the framework in development.

Stevens, as far back as in 1989, had identified four stages of supply chain integration, where the first three stages refer to supply chain integration within an individual firm (intra-firm integration), whilst the final stage simply refers to inter-firm integration. The value chain of an organisation depicted by Porter (1985) can be applied to the first three stages identified by Stevens (1989). These models mainly focused on integration of processes within a single organisation. However during the past decade, several models have been proposed both by academics and practitioners which focus on integration of processes with external organisations within a supply chain. These non-construction specific models are discussed below.

3.2.1 The value chain model

Porter proposed the value chain model, in 1985 (refer Fig. 2.4), and classified an organisation’s activities into 5 primary activities and 4 support activities. He explained that value is added to a product an organisation is manufacturing via all of these activities, and that this is how an organisation creates a profit margin. However, the model is criticised for not explaining how these activities interact with each other and how integration can be improved (Choi, 2000). De Wit and Meyer (1994) state that the model is only focused on cost analysis and does not incorporate aspects such as company mission, politics, leadership and corporate culture. Yet this was the case in the 1980s, where most of the SC issues were dealt with at operational level disparately.

Porter (1985) stated that 'every firm is a collection of activities that are performed to design, produce, market, deliver, and support its product'. This definition is partially relevant to most supply chains as well. Whilst a single organisation may execute all of these activities, a SC also may perform all of these activities to deliver value to customers and create profits for each SC member, based on the value they created and market conditions. For example, to deliver a complex constructed facility to a construction client design consultancies, main contractors, trade and specialist sub-contractors, material suppliers, etc have to work together as SC members. However, this was not the focus of Porter (1985) during an era SCM was not commonplace. Yet it provides insights with regard to necessary integration across departments when manufacturing a product.

3.2.2 An early SCM model

The model produced by Stevens (1989) encapsulates the transition of an organisation across four levels with regard to its management styles, organisation structure, integration of separate functions, adaptation to market conditions, etc. Hence this model does offer something more than an economic model, as Porter's (1985) model is criticised for. From an SCM perspective this model contributes knowledge with regard to integration with external organisations, even in a single stage, as far back as 1989. The four stages, according to Stevens (1989; cited in Pryke, 2009) are as follows:

Baseline organisation: Classical management; motivation by profit maximisation; functional specialisation; slow to adapt to market and slow to exploit innovative opportunities.

Functionally integrated company: Starting to focus on customer service; competitive advantage achieved through some internal integration of disparate functions.

Internally integrated company: Systems approach to customer service; optimal information flow between departments; medium-term planning; cross-functional management – product focused structure.

Externally integrated company: Transparent system of materials and information exchange internally and externally; long-term planning and long-term relationships with partners; use of internal cross-functional management structures, product related; supplier networking groups implemented.

Stevens' model demonstrates a transition from an internally integrated organisation to a fully-integrated supply chain in one step, at the fourth level. Although Stevens (1989) recognises that an organisation requires going through several stages prior to achieving a fully integrated organisation, he fails to recognise the same for the development of an integrated SC among several organisations. Two decades from then on has shown that development of an integrated SC also requires a similar amount of stages.

3.2.3 Business process maturity and supply chain integration

Figure 3.1 depicts a supply chain maturity model proposed by Pittiglio, Rabin, Todd & McGrath (PRTM) in 2002 which contains four stages: Functional focus, Internal integration, External integration and Cross-enterprise collaboration. This model is based on the concept 'process maturity drives supply chain performance' (PRTM, 2002). This is a model developed by a group of practitioners, who are management consultants to technology based organsations in the US. They claim to be leaders in SCM, and have codeveloped the SCOR model (refer 3.2.7) which consequently became an industry standard model.

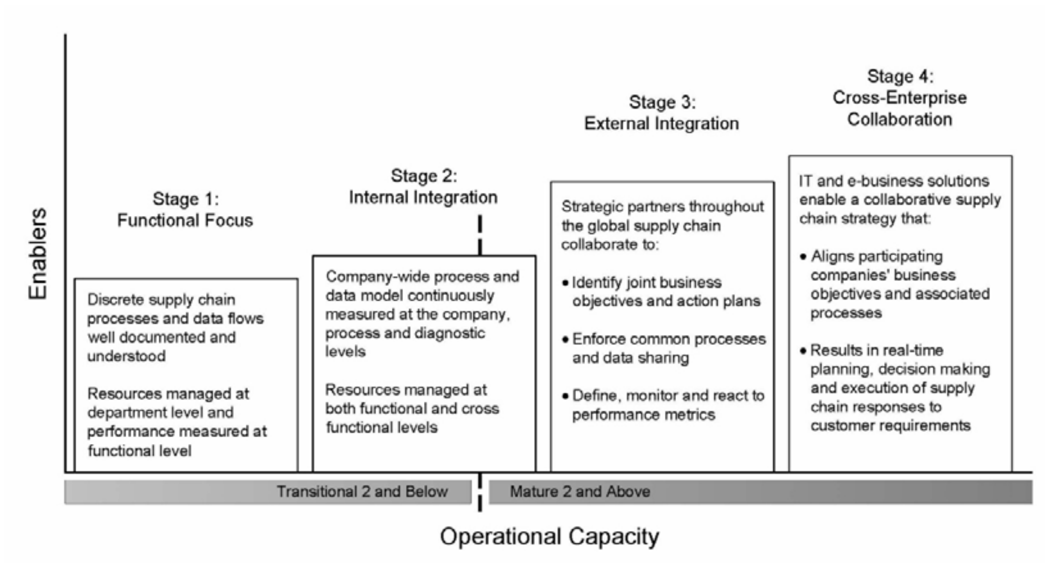

Figure 3.1 - Supply chain maturity model SM (PRTM, 2002, p.4)

The above model is not supported by empirical evidence. It seems to encompass the first three levels of the Stevens (1989) model in its first two stages, and the fourth level of the Stevens (1989) model in it last two stages. PRTM (2002) identify that investing in selected aspects of a supply chain yields higher returns. They also identify that it is necessary to make strategic trade-offs between cost, service levels, lead times, and assets accordingly. Moreover PRTM (2002) suggest that organisations that perform excellently in the 'Deliver' process identified in the SCOR model (refer section 3.2.7) gain a strategic advantage. It is important to note that this is the only process besides the ‘Return’ process which has a customer interface. According to a survey carried out by PRTM (2002) very few organisations have been effective in designing and implementing successful ‘Deliver’ strategies.

3.2.4 A demonstrative model on supply chain success in the manufacturing industry and investment in IT

Hoffman and Reiner in 2006 proposed a model which closely resembles the maturity model depicted in Figure 3.1. The four levels of maturity proposed by them relate to the level of integration of business processes. Hence this model can be used as a maturity model for supply chain integration. In fact this model closely resembles the supply chain maturity model proposed by the practitioner group PRTM (2002). Hoffman and Reiner (2006, p.219) present these categories as levels of maturity:

Level 1 – Disconnected processes: At this level there is no or low degree of integration. The processes are functionally oriented and SC planning is done independently by each organisation. The SC members tend to work in silos.

Level 2 – Internal integration: At this stage organisations are functionally oriented, but there is integration of some functional information. Jointly developed forecasts will be applied throughout the organisation.

Level 3 – Intra-company integration and limited external integration: At this stage organisations will be cross-functionally organised. The SC planning process will involve key suppliers and customers.

Level 4 – Multi-enterprise integration: At this stage organisations will have multi-enterprise processes and common business objectives. There will be collaboration across the entire SC, and will operate as one virtual organisation.

Hoffman and Reiner (2006) collected empirical evidence from 60 organisations within 68 different supply chains in the manufacturing industry to characterise the linkage between supply chain performance and maturity of business processes and IT infrastructure. They supported each level of business process maturity identified above with a corresponding IT structure. This research demonstrates that investment in resources correlates to the degree of process maturity or SC integration. The corresponding IT infrastructure for each stage of maturity according to Hoffman and Reiner (2006) is as follows:

Level 1 – Independent systems and batch processing leading to redundant data across organisations. There is heavy usage of spreadsheets and manual processing of data for decision making.

Level 2 – Planning tools are used to process and share data across the SC.

Level 3 – All data and processes would be made visible to the entire SC, although access would be limited to a few key SC members.

Level 4 – All data and processes are shared internally and externally.

3.2.5 A generic framework for supply chain management with a 'relational view'

Chen and Paulraj (2004) produced a research framework for SCM, which is based on 'cross-enterprise and interdisciplinary literature' and grounded on the strategic management theory of 'collaborative advantage' in contrast to 'competitive advantage'. They also claim that the conceptual framework draws on the 'relational view of interorganisational competitive advantage' contrary to the 'resource-based view'. However, they acknowledge that the relational view does encompass the 'resource-based view' where the whole SC is considered the unit of analysis when considering resources, opposed to considering a single organisation as the unit of analysis. This conceptual framework (refer Fig. 3.2) gives an indication of some critical success factors in managing supply chains. However, the framework does not describe different levels of these contributory factors in operating SCs, nor provides a scale to measure each factor. Hence this model would not be useful in assessing integration of SCs in the construction industry, or in understanding improvements.

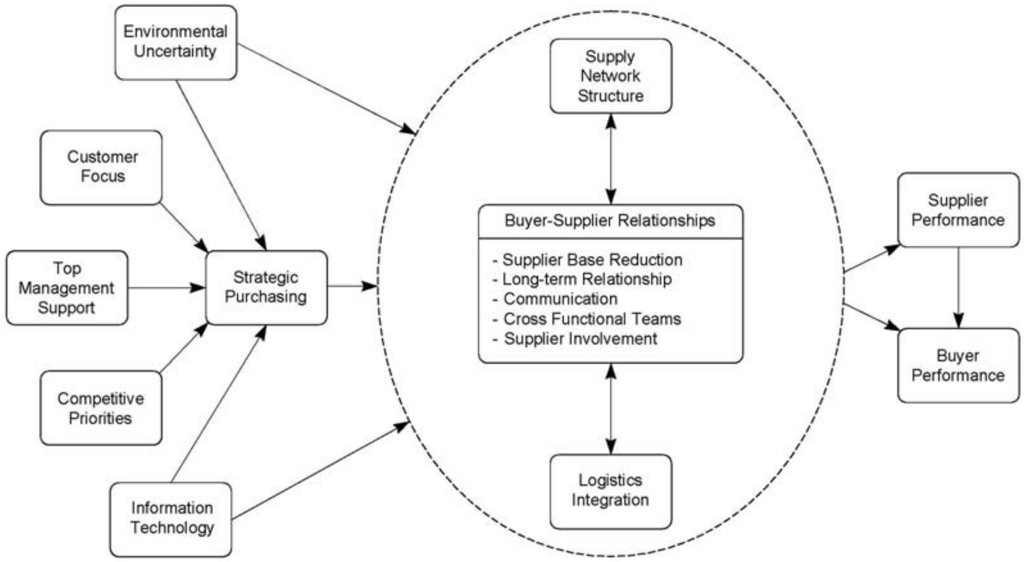

Figure 3.2 - A research framework for SCM (Chen and Paulraj, 2004, p.121)

3.2.6 The SCM maturity model (Lockamy and McCormack, 2004)

Research carried out by Lockamy and McCormack (2004) has produced a supply chain maturity model based on business process orientation (refer Fig. 3.3). This academic research is supported by empirical evidence from a variety of industries. The model suggests 5 levels of maturity: Ad hoc, Defined, Linked, Integrated and Extended.

This model has been adapted from the process and capability maturity model published by the Software Engineering Institute in 2002 (Lockamy & McCormack, 2004). The model encompasses the core management processes (Plan, Source, Make and Deliver) identified in the SCOR model (refer section 3.2.7) proposed by the supply chain council (refer Table 3.1). The model depicts the shift from individual planning of processes to central planning of processes and the increased integration of the core management processes: Plan, Source, Make and Deliver when moving to more mature stages of the model. The fifth level is depicted as a virtual organisation where all SC members are involved in matters real-time, enabled via IT facilities. This level is similar to Level 4 of Hoffman and Reiner's (2006) model (refer 3.2.4).

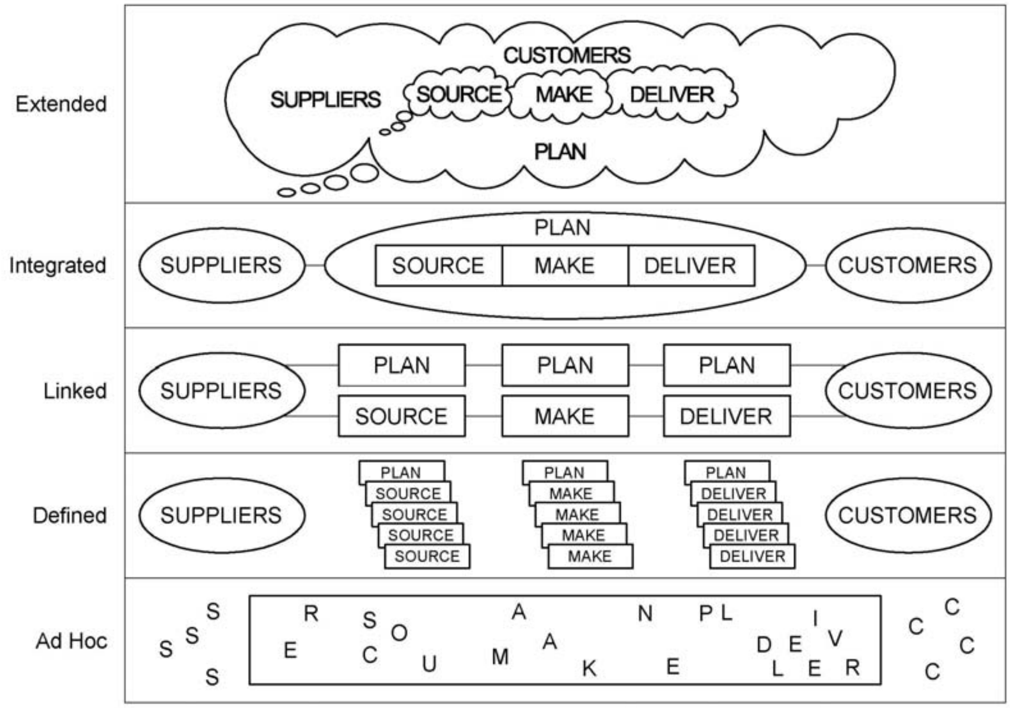

Figure 3.3 - The SCM maturity model (Lockamy & McCormack, 2004, p.276)

3.2.7 The supply chain operations reference (SCOR) model

The supply chain council (SCC) developed and published the Supply Chain Operations Reference model (SCOR) version 8.0 in 2006. It is claimed to be a cross industry model that allows simple and complex SCs to be analysed. However, little evidence can be found of its use in construction. A detailed model is not made available, but is intended for potential users to contact the SCC. Moreover empirical support for this model is not available, apart from anectdotal evidence published from the SCC as it is a proprietary model. The SCC (2006) proposes four process levels and the SCOR model comprises of the first three levels of process detail. The SCOR model is based on five core management processes identifiable within an organisation in a generic/typical supply chain. The five SCOR Process definitions are listed in Table 3.1 below.

Table 3.1 - SCOR Process Definitions (SCC, 2006, p.7)

SCOR Process	Definitions
Plan	Processes that balance aggregate demand and supply to develop a course of action which best meets sourcing, production and delivery requirements
Source	Processes that procure goods and services to meet planned or actual demand
Make	Processes that transform product to a finished state to meet planned or actual demand
Deliver	Processes that provide finished goods and services to meet planned or actual demand, typically including order management, transportation management, and distribution management
Return	Processes associated with returning or receiving returned products for any reason. These processes extend into post-delivery customer support

SCC (2006, p.6) explains its levels as follows:

Level 1 – Defines the scope and content for the SCOR model, and performance targets are set.

Level 2 – A company's supply chain is "configured-to-order" from core "process categories." Companies implement their operations strategy through the configuration they choose for their supply chain.

Level 3 – Defines a company's ability to compete successfully in its chosen markets, and consists of Process element definitions; Process element information inputs, and outputs; Process performance metrics; Best practices, where applicable; System capabilities required to support best practices; and Systems/tools. Companies "fine tune" their Operations Strategy at Level 3.

Level 4 – Companies implement specific SCM practices at this level. Level 4 defines practices to achieve competitive advantage and to adapt to changing business conditions. Thus the solution will vary from one organisation to the next.

It should be noted that the levels identified in the SCOR models are the steps of applying the model to an organisation. These levels do not present levels of integration as in PRTM (2002). Thus eventhough it is presented as a cross industry standard, the model does not fill the knowledge gap identified due to lack of description of levels of integration, lack of evidence of application in construction and empirical evidence.

3.2.8 A measurement model for web-enabled supply chain integration (McLaren, 2006)

A more recent research carried out by McLaren (2006) produces a model of five stages/levels of supply chain integration. He has focused on web-enabled supply chains of manufacturing industries in the US. He developed his model identifying five levels of supply chain integration based on models proposed by Moncrieff and Stonich (2001) and PRTM (2001). He also compares his model to the model of Poirer and Bauer (2001). The five levels of supply chain integration proposed by McLaren (2006) are;

Level 1 – Functional Focus

Level 2 – Internal Integration

Level 3 – Linked Network

Level 4 – Integrated Network

Level 5 – Optimised Network

The observable patterns of each of these levels including a comparison to two other models are shown in Table 3.2. McLaren's (2006) model was designed for e-business. His questionnaire survey was conducted among five web-enabled supply chains in the manufacturing industry. His questionnaire adapted from Moncrieff and Stonich (2001) gives an indication of how to move to higher levels of integration containing 15 dimensions identifiable within a SC. The 15 dimensions were SCM Strategy, Performance Management, Processes, Decision-Making, Demand Planning, Supply Planning, "Source" Strategy, Commodity and Spend Management, Supplier Development and Management, Sourcing Organization and Infrastructure, "Make"

Strategy, Production Scheduling, Inventory Management, “Deliver” Process Management, Order Management, and Logistics and Invoicing. McLaren (2006) identifies that organisations in all industries need not aspire to create ‘Optimised Networks’. Hence he has proposed a ‘measurement model’ instead of a ‘maturity model’. This is an interesting proposition for the construction industry, which is still striving towards ‘optimised networks’. Due to the short-term nature of some projects in the construction industry, it might be that it is not cost efficient to formulate ‘optimised networks’ with some SC members. It may be that a lower level of integration would be most beneficial to some construction organisations.

Table 3.2 - The five levels of supply chain integration (McLaren, 2006, p.3)

	Level 1 Functional Focus	**Level 2 Internal Integration**	**Level 3 Linked Network**	**Level 4 Integrated Network**	**Level 5 Optimized Network**
Observable Patterns	Discrete processes managed at the department level.	Company-wide processes managed at both functional and cross-functional process levels.	Core processes managed internally; info sharing with external partners. Outsourcing of non-core processes.	End-to-end process mgmt., coordination, & collaboration with external partners. Alignment of business objectives and processes of each partner	Standardized, modular processes coordinated in real-time and executed by most capable partners.
	Performance measured at the functional level.	Performance measured at the company, process, and diagnostic levels.	Metrics defined by one firm. Joint performance monitoring and correction with partners.	Joint metrics definition, monitoring, and correction with external partners.	Standardized performance metrics monitored and corrected jointly at the company, process, and diagnostic levels.
Term used in Moncrieff and	Functional Focus	Internal Integration	External Integration		Cross-Enterprise

	Level 1 Functional Focus	**Level 2 Internal Integration**	**Level 3 Linked Network**	**Level 4 Integrated Network**	**Level 5 Optimized Network**
Stonich (2001)					Collaboration
Term used in Poirier and Bauer (2001)	Internal Supply Chain Optimization	Network Formation	Value Chain Constellation	Full Network Connectivity	

3.3 Discussion of non-construction specific models available in literature, and their application to the construction industry

There is a plethora of generic SCM models produced by industry specialists, as well as academics available in literature, most of which have been produced within the last 15 years. Some of these were discussed in the previous section, where some similarities and dissimilarities between different models were revealed. It was noted that these models observed SCs as a process to manage by implementing a certain organisational structure in individual organisations, which will ultimately allow a number of organisations to be well integrated. This approach was observed in industries such as the IT industry as well, which is project oriented. Hence, despite the project-based nature of the construction industry, the industry can make use of a model which has an organisational perspective. An organisational view gives a longer term perspective than a project-based view.

Different indicators were encompassed in different models such as IT (Hoffman and Reiner, 2006; PRTM, 2002; Lockamy and McCormack, 2004), information exchange (Stevens, 1989), collaborative relationships (Stevens, 1989), collaborative planning (Lockamy and McCormack, 2004; PRTM, 2002; Stevens, 1989), responsiveness to customer (Stevens, 1989, SCC, 2006), top management support (Chen and Paulraj, 2004) and performance measurement (PRTM, 2002; McLaren, 2006), all of which can be applied to construction SCs. It appears that some of the critical factors to the construction industry such as collaborative relationships, information exchange and responsiveness to customer is emphasised in the Stevens (1989) model, rather than in the more modern models. One inference of this observation is that Stevens (1989) model is still a very comprehensive model, when compared to the modern SCM models. Another inference is that most industries have improved so much in the 1990s with regard to collaborative relationships or information exchange, which makes it unnecessary to include such factors explicitly in a SCM model. Unfortunately this assumption cannot be made about the construction industry which still is dealing with adversarial attitudes among SC members.

It was noted that some models use stages of integration to decribe the development of SCs, and some models do not. All SCM models that classified stages of integration used 4-5 stages of integration. It was discussed that some models explained two stages of another model in a single stage, and vice versa. Hence one can argue that there is the potential to develop a model with more than 4-5 stages of integration. However, as observed when explaining the Stevens (1989) and PRTM (2002) models, some of these stages are more oriented towards integration within an organisation, than integration with external organisations. Thus it can be concluded that 4-5 levels of integration would be sufficient for a SCM model produced for the construction industry.

3.4 Models on supply chain management proposed for the construction industry

SCM is a concept which is extensively advocated and promoted throughout the construction sector via many initiatives and networks (Egan, 1998; Egan, 2002; Wolstenholme et al., 2009), although some critiques such as Briscoe and Dainty (2005) claim that construction SCs will never achieve fully integrated SCs due to the construction output being subject to cyclical demand. SCM is assumed by some organisations to be highly relevant to the construction sector and remains central to arguments for efficiency gains (Fernie and Thorpe, 2007). The ‘use of innovative managerial concepts is argued to make particular projects in the construction sector higher performers’ (Fernie et al., 2006). Moreover, government sponsored reports such as Egan (1998) and Wolstenholme et al. (2009) advocated the integration of construction processes and products in order to enhance value delivered to construction clients.

In this endeavour Sarshar et al. (1999) embarked on a project titled SPICE (Standardised Process Improvement for Construction Enterprises) at the University of Salford with the aim of developing a capability maturity model for the construction industry. However upon validation of the model it was revealed that the model only relates to process improvement within a single organisation. Later on Sarshar et al (2000) converted this model for the use of process improvement within construction organisations. Similarly another SCM model developed in the recent years by Khalfan & Maqsood (2013) focues on waste minimisation of the Australian construction industry. Hence the UK remains without an SCM model which can be applied across the full spectrum of SCM.

Love et al. (2004) produced a project based SCM model which they called ‘a seamless project supply chain management model’ (refer Fig 3.4). This model follows through the stages of a project, starting from the inception of a project to the operation of facility by the owner reminding you of some key activities that need to take place in order to manage the SCs. Hence the model deals with some operational issues applicable to SCM, based on 6 semi-structured interviews. They do recognise that due to the limited collection of data to validate the model, that it cannot be applied to the whole industry. Further, due to the lack of classification of levels of integration within a certain activity, the model does not lend itself to the assessment or benchmarking of integration of construction SCs.

A model developed by the Australian Expert Group for Industry Studies (AEGIS) in 1999 for the Building and Construction Industry Cluster discusses the construction supply chain based on ‘five main sectors: onsite services; client services; building and construction; supplies and products; tools, fasteners, machinery and equipment’ (O’Brien, London and Vrijhoel, 2002). However, they explained that this model required more empirical data to refine the model, and that due to the large number of small to medium sized organisations involved in construction supply chains made it difficult. Similar models have come into existence in the UK over the last decade, which are not empirically tested, but produced and circulated in the construction industry.

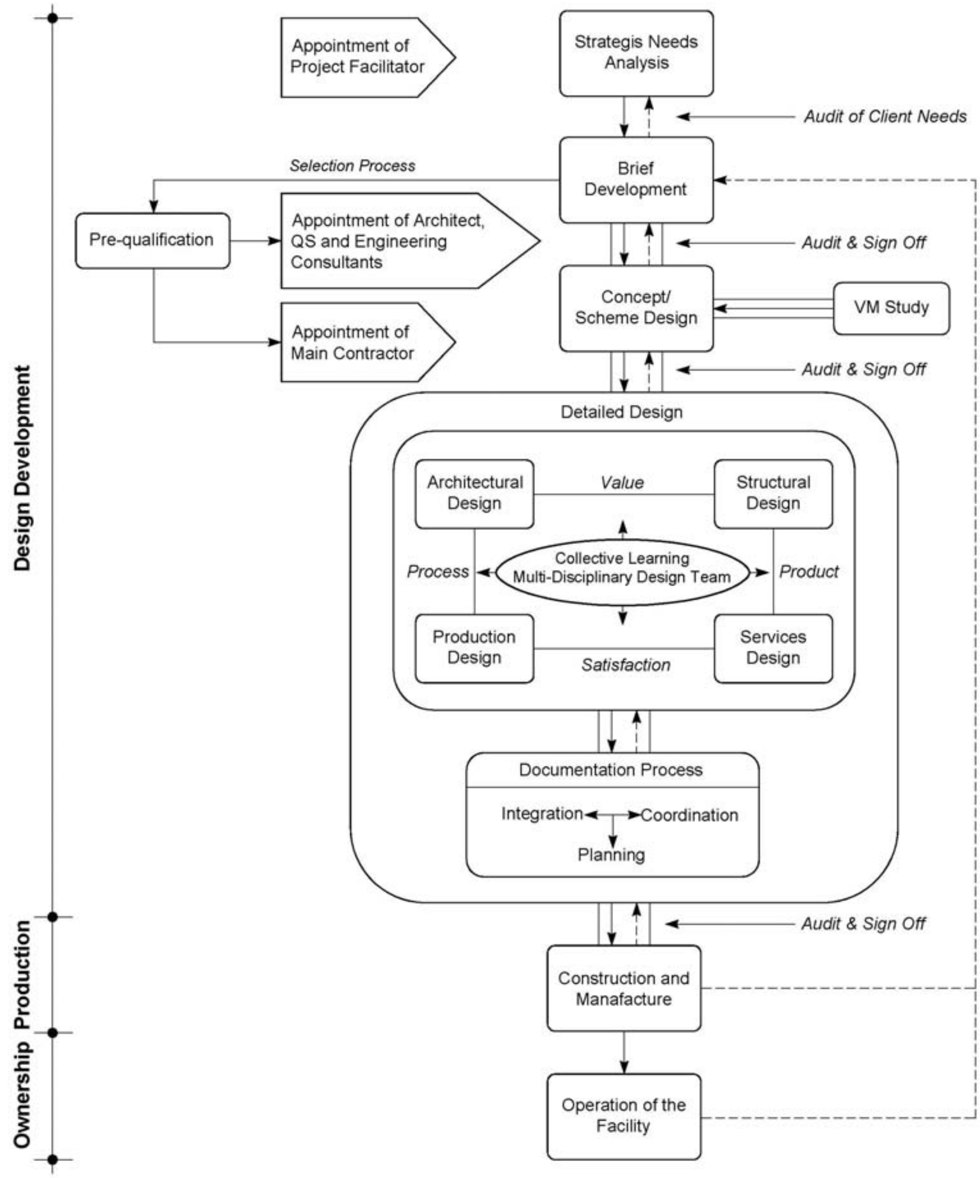

Figure 3.4 - A seamless project SCM model (Love et al., 2004)

Vaidyanathan and Howell (2007) proposed a conceptual framework for the US construction industry, which they called the 'construction SC maturity model'. They developed this model based on research carried out in the manufacturing and IT industries, and it was not validated using data from the US construction industry. Their model is somewhat similar to the PRTM (2002) model described previously. The four stages of this maturity model are defined as Ad-hoc, Defined, Managed and Controlled.

It is interesting to note that Vaidyanathan and Howell (2007) state that the US construction industry is currently at the Ad-hoc level. This somewhat contradicts the findings of the SPICE project described previously, which was conducted in the UK. According to Sarshar et al. (1999) the construction industry is a relatively mature industry compared to the software industry, in terms of shared understanding of customs and working practices. This is further reinforced by the UK government which advocates long-term contracts for public organisations in the construction industry. After all, procurement methods practiced in an industry have an effect on the optimum level of SC integration.

In recent years Aloini et al. (2012) developed a conceptual model based on extant SCM models available in literature, with the intention of adapting the model to the construction sector. They currently present the model with contextual factors, antecedents and SCM benefits aligned, and hope to further develop the model as part of a wider project. There is no emipirical evidence to support this model. Further the model does not encompass stages of integration. Hence the knowledge gap identified in previous chapters, of a framework encompassing stages of integration, still exists.

Thus due to varying methods of procurement based on country which may affect implementation of SCM, lack of emprical evidence to support the models, lack of applicability in general to SCs (due to the models being focused on a niche such as waste minimisation) and lack of demonstration of stages of SCM, the need to develop a framework for the construction industry remains after two decades of academic interest in the subject.

3.5 Critical success factors for a SCM framework for the construction sector

The discussions of the previous sections revealed the need to develop a SCM framework that is elaborated across 4-5 levels of integration, which will allow the construction industry to assess and improve their SCs. It was also established that such a framework should encompass a set of criteria that is relevant to the construction industry. Some of the factors used in generic models, such as IT (Hoffman and Reiner, 2006; PRTM, 2002; Lockamy and McCormack, 2004), information exchange (Stevens, 1989), collaborative relationships (Stevens, 1989), collaborative planning (Lockamy and McCormack, 2004; PRTM, 2002; Stevens, 1989), responsiveness to customer (Stevens, 1989, SCC, 2006), top management support (Chen and Paulraj, 2004) and performance measurement (PRTM, 2002; McLaren, 2006) can be incorporated in a construction framework. However, it is important that all criteria are backed up within construction related literature to ensure relevance of a proposed framework. Hence this section discusses 13 Critical Success Factors (CSFs) that are important to the integration of construction SCs, originated based on generic SCM models and further expanded based on SCM related research carried out in the construction industry. The aim of this process was to compile success factors based on literature that are relevant to a construction SCM framework, which can be later tested for their importance via a primary survey. These CSFs are included in Table 3.3 and discussed from section 3.5.1 onwards.

The report on 'Accelerating change' from Egan (2002), following the Egan report in 1998, suggested a few drivers for change in the construction industry with the target of improving on cost, time, quality, productivity, profit, etc. and improving project processes such as 'partnering the SC' (refer Fig 3.5). Presumably some or all of these drivers of change can be included as CSFs in a SCM framework for the construction industry. Moreover, it is important that the reader can distinguish between 'drivers for change' and 'targets for improvement' in Fig 3.5. The CSFs to be incorporated in the proposed SCM framework are similar to driver for change. They are the stimuli in promoting well integrated SCs; whereas the performance metrics or KPIs or targets for improvement as described in Fig 3.5 are what can be expected out of well integrated SCs.

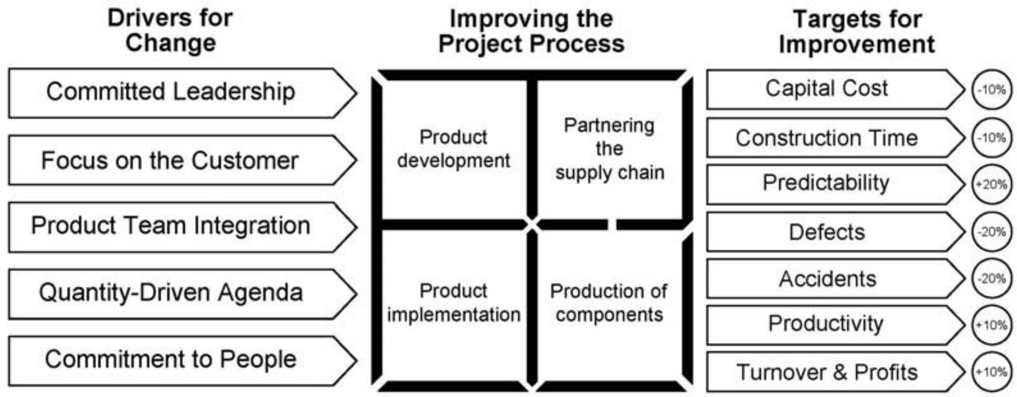

Figure 3.5 - Model for accelerating change in the UK construction industry (Adapted from Egan, 2002)

The research conducted by Yeung et al. (2009) on relationship measures in the Australian construction industry provides some insight into a further number of CSFs that could be incorporated into a construction SCM framework. The measures identified in their research are internal and external communication (also supported by PRTM (2002) and Hugos (2006), meeting effectiveness, accomplishment of objectives (PRTM, 2002), utilization of resources (Hoffman and Reiner, 2006), problem solving, creativity and synergy, timely evaluation and appropriate response (McLaren, 2006; PRTM, 2002), definition and adherence to roles and responsibilities, continuous improvement and teamwork.

The relationship measure 'creativity and synergy' advocated by Yueng et al. (2009) can be derived through CSFs trust, good working relationships, appropriate procurement methods, long-term working relationships (continuity of work) and a suitable vision, mission, etc. Hence 'creativity and synergy' is a result of good SC integration rather than a CSF leading towards SC integration. The importance of distinguishing between the benefits derived from integrated SCs and the measures leading towards SCs was explained earlier.

Table 3.3 - Supporting literature for the 13 citical success factors (CSFs)

	Critical Success factors (CSFs)	Supporting Literature
1	Positive attitude and approach to working relationships	Egan (2002), Brewer et al. (2005), Gunasekera et al. (2008), Yeung et al. (2009), Lockamy & McCormack (2004).
2	Level of trust between SC members	Yeung et al (2009), Egan (1998), Egan (2002), Akintoye et al. (2000).
3	Availability and use of IT for collaboration between SC members	Stevens (1989), Hoffman and Reiner (2006), McLaren (2006), Akintoye et al. (2000), Chen and Paulraj, (2004), PRTM (2002).
4	Promoting engagement of all SC members at the client briefing stage	Egan (2002), Stevens (1989), Love et al. (2004).
5	Support and commitment of leaders/ senior management of all SC member organisations towards integrated SCs	Egan (2002), Brewer et al. (2005), Yeung et al. (2009), Akintoye et al. (2000), Chen and Paulraj (2004).
6	Procurement methods used to procure projects	Rowlinson and Cheung (2011), Akintoye et al. (2000).
7	Length of project duration or Continuity of work to sustain the SC	RICS (2012), Briscoe et al (2001), Fearne and Fowler (2006), Brewer et al. (2007).
8	Extent of communication between SC members	Stevens (1989), Yeung et al. (2009), Akintoye et al. (2000), Naim and Barlow, (2000).
9	Existence of a system to measure performance of SC members	Egan (2002), McLaren (2006), Yueng et al. (2009).
10	Existence of a strategy for training and development of SC members	Egan (2002), Akintoye et al. (2000)

	Critical Success factors (CSFs)	Supporting Literature
11	Availability of a vision, mission, strategy, policy and procedures for management of SC	PRTM (2002), Moncrieff and Stonich (2001), Yeung et al. (2009).
12	Existence of a protocol for conflict resolution among SC members	Richbell (2008), Yeung et al. (2009).
13	Degree of collaboration, between SC members, when making key decisions	Lockamy and McCormack (2004), PRTM (2002), Yeung et al. (2009), Love et al. (2004).

3.5.1 Positive attitude and approach to working relationships

Recommendations and targets of the report Accelerating change (Egan, 2002) encompassed partnering the SC as essential for improving the project process. Sir John Egan, in the same report (p.7), stated that "Integrated team working is key. Integrated teams deliver greater process efficiency and by working together over time can help drive out the old style adversarial culture, and provide safer projects using a qualified, trained workforce." This vision requires construction professionals to move from a 'win-lose' disposition towards a 'win-win' outlook. The underlying assumption in the construction industry in the past was that for a construction organisation to make extra profit, someone else has to forego something. This led to the adversarial culture in the industry. However, SCM practices in other industries have shown that organisations working together can create synergies. This meant that the sum of total can be more than the addition of the separate components. This opposes the previous underlying assumption that the sum of the total is constant, which led to construction organisations working aggressively to capture the largest possible share of the sum of total at other organisations' losses. Hence working positively with each other is becoming an important, relevant and practical issue for integrated SCs. Thus a construction SCM framework for the construction sector needs to encompass CSFs such as attitude and approach to working relationships between SC members (also supported by Brewer et al. (2005), Yeung et al. (2009), Gunasekera et al. (2008) and Lockamy & McCormack (2004).

3.5.2 Level of trust between supply chain members

Trust is an important dimension to improve on if transparency and coordination in a relationship is to be improved. Yeung et al (2009) identifies internal and external trust as relationship measures in their research conducted in the Australian construction industry. Akintoye et al. (2000) also found that trust between SC members is considered crucial when promoting SCM ethos in the UK construction industry. Egan (2002) and Egan (1998) reports imply that this is a key dimension to improve on in order to move away from the culture of adversarial relationships in the construction industry. Since then the use of forms of contracts such as the NEC (New Engineering Contract), where the importance of trust between parties to contract is emphasized, has steadily increased. The increase is significant in high value projects according to the survey in 2010 by the RICS in partnership with Davis Langdon. Thus, trust is an important, relevant and deliverable CSF that should be incorporated in a construction SCM framework.

3.5.3 Availability and use of IT for collaboration between supply chain members

Collaborative IT provision is a central driver that is embedded in many non-construction specific SCM models that were discussed earlier in this chapter. Apart from the early SCM model of Stevens (1989), all other decriptive models have made some reference to the requirement of IT to integrate SCs. Stevens (1989) too has referred to internal and external information exchange in his model, which in modern days assume an IT infrastructure. Hoffman and Reiner (2006) were able to demonstrate based on empirical research that there is a linkage between the level of integration and IT infrastructure in SCs. Moreover facilities such as BIM software are making integration via IT a reality in the construction industry. BIM can be used for social e-business and improving collaboration in the construction industry according to Costa and Tavares (2012). Hence collaborative IT infrastructure is a CSF for integration of SCs, which is a practical and relevant provision in the construction industry. However, due to the short-term nature of some projects the construction industry may struggle to generate a return on their investment in IT due to the short payback period involved. In such scenarios we need to accept that some industries may have a limit with regard to their level of integration, making McLaren's (2006) claim for a measurement model instead of maturity model more appropriate.

3.5.4 Promoting engagement of all supply chain members at the client briefing stage

Focus on the customer is recommended as a driver for change in the model produced by Egan (2002). Stevens (1989) too recognise the importance of the customer, and the need for an integrated SC to be responsive to customers. Most SCM models include the client when demonstrating linkages. For the construction industry understanding the customer or the client is critical when the product has to be designed and constructed based on information elicited from the client per project, due to the bespoke and complex nature of most projects. Thus Love et al. (2004) include the activity 'Audit of client needs' in the very early stages of their SCM model. It is necessary that all SC members are included at the client briefing stage so that clients' needs are properly understood and to be responsive to his/her needs.

3.5.5 Support and commitment of leaders/ senior management of all supply chain member organisations towards integrated supply chains

Egan (2002) identifies committed leadership as a driver for change for partnering the SC. This is further supported by Brewer et al. (2005), Akintoye et al. (2000) and Chen and Paulraj (2004) who mention that commitment of senior managers in essential in improving SCM practices. After all, the culture, practices or processes of an organisation cannot be changed or improved without the commitment of the leader. Yeung et al. (2009) recognised that both internal and external leadership are crucial in promoting integration, based on their research in the Australian construction industry. This would mean that the senior managers need to demonstrate leadership not only within a single organisation, but across organisations who needs to be integrated as part of the SC. In a more practical sense, it would mean that the commitment of senior managers of all the SC member organisations would be required for integration to be a success.

3.5.6 Procurement methods used to procure projects

Akintoye et al. (2000) explain that major reforms to procurement methods were called for by government reports such as Latham and Egan, in order to promote SCM in the construction industry. Traditional forms of procurement which encouraged the low-bid culture was thought to promote adversarial relationships within the construction industry. Hence different forms of collaborative procurement methods came into use, alongside forms of contract such as NEC which promote trust and working together harmoniously with win-win disposition over the last decade. The increase in collaboration potential across different types of procurement methods in the construction industry is identified in Figure 3.6.

Different forms of collaborative procurement were discussed in the previous chapter. It is apparent that these procurement methods promote ethos of coordination and good working relationships, based on trust, early involvement of SC members, long-term working relationships, etc. Hence it is essential that a relevant procurement method is chosen to facilitate good SCM practices.

Procurement method	**Degree of collaboration**
Traditional Approach	
Minor Works Contract	
Road Construction Contract	
Road Construction Contract with	
Relationship Management	**Increasing**
Construction Management	**Integration**
Early Contractor Involvement	
Design and Construct	
Build Operate Transfer	
Alliance	

Figure 3.6 - Procurement method and collaboration potential (Adapted from Rowlinson and Cheung, 2011)

3.5.7 Length of project duration or Continuity of work to sustain the supply chain

In response to Briscoe et al (2001) statement that there are attitudinal problems among SC members, Fearne and Fowler (2006) state that it is due to the short-term project-oriented nature of the construction industry. This is one of the reasons why the construction industry claims to be unique, particularly in comparison to the manufacturing industries. It is difficult for the construction industry to directly apply management principles tried and tested in manufacturing industries due to these differences. However, in recognizing these differences between industries, we have the opportunity to breakdown some barriers by promoting long-term working relationships via encouraging construction organisations to form mechanisms (such as framework agreements) which will allow them to work together beyond a single project. RICS (2012) has recognised that the use of collaborative procurement methods in the industry is mostly for high value projects, which probably have long project durations. Whilst this should be further encouraged, it is important that the industry takes the opportunity to create long-term relationships even for short-term, lower value projects by working together on several different projects. This is because continuity of work has a significant impact on promoting SCM ethos. Long-term working opportunities will also make investment in resources in construction projects more worthwhile, as Brewer et al. (2007) recognise that investment in IT as a paramount concern where there are short payback periods.

3.5.8 Extent of communication between supply chain members

Stevens as far back as 1989 recognises information exchange as essential to integrated SCs. Yeung et al. (2009) too recognise that internal and external communication is vital in relationship measures in the Australian construction industry. Naim and Barlow (2000) and Akintoye et al. (2000) also found in their SCM surveys in the UK that communication is vital for good SCM. In the modern days there are several modes of communication such as face-to-face, telephone, email, snail mail, social networking websites and other inter or intra-nets or databases that an organisation may be using. The extent and the way you communicate using any of these methods is important. This is recognised in all forms of contracts; particularly the NEC elaborates on the clarity and the timeliness of communication, underpinned by trust between parties.

Moreover, software such as BIM can be used for social e-business and improving communication in the construction industry according to Costa and Tavares (2012).

3.5.9 Existence of a system to measure performance of supply chain members

McLaren (2006) incorporates performance measurement in his measurement model for integrated SCs. Without measuring performance SC members may not be motivated to perform well or improve continuously. Hence Egan (2002) encourages performance measurement in the construction industry. Continuous improvement, timely evaluation and appropriate response to evaluation are recognised as important to improve relationships in the construction industry by Yueng et al. (2009). Thus it is necessary that a construction SCM framework includes performance measurement as one of its CSFs.

3.5.10 Existence of a strategy for training and development of supply chain members

Egan (2002) recommends commitment to developing people in their model to improve the construction industry. Training and development of employees within an organisation has been recognised as essential for many decades in all industries. The same philosophy applies to a firm’s SC members, if they want to continuously improve their SC’s output. Akintoye et al. (2000) recommended all levels of the construction industry be trained and educated regarding SCM subsequent to their survey on collaboration in the UK construction industry. Hence the training and development strategy should be included in an SCM framework.

3.5.11 Availability of a vision, mission, strategy, policy and procedures for management of supply chains

For an organisation to be a success it needs to have a vision, mission, etc. Similarly a construction organisation needs to consider what its vision, mission, strategy, policy and procedures should be for managing its SCs. This would allow all SC members to work towards integrated SCs with a similar mindset; for example knowing if the goal is to achieve maximum responsiveness or lowest costs. PRTM (2002) recognised that aligned objecives and policies lead to better integrated SCs. Moncrieff and Stonich (2001) recognised the importance of a stratgy when promoting SCM. Similarly Yeung et al. (2009) found out that accomplishment of objectives and adherence to roles and responsibilities are necessary for good relationships to be formulated in the Australian construction industry. The first step towards this measure would be to make available a vision, mission, etc. to its SC members.

3.5.12 Existence of a protocol for conflict resolution among supply chain members

All relationships have the potential for conflict. The construction industry in particular has been referred in the past as a very litigious industry (Richbell, 2008). Whilst procurement methods such as partnering, forms of contract such as NEC or other relationship measures mentioned by Yeung et al. (2009) provide the prospective of minimizing conflict, it is imperative that a protocol for conflict resolution is in existence for SC members to manage conflicts. This would help create an environment for all SC members where they know their problems can be discussed. Yeung et al. (2009) found in their research that problem solving is an important measure in relationships.

3.5.13 Degree of collaboration, between supply chain members, when making key decisions

Non-construction SCM models such as from Lockamy and McCormack (2004), PRTM (2002) propose real time planning and decision making at the highest level of integration, via the provision of collaborative IT infrastructure. Yeung et al. (2009) refers to effective meetings as crucial in relationship measures in the construction industry. Love et al. (2004) in their construction SCM framework identifies a process referred to as ‘collective learning’ at the design development stage, which is similar to collaboration when making decisions with regard to design. Such collaboration is made easier and more practical with IT facilities such as BIM in modern days.

3.6 Summary of chapter

The chapter discovered some commonalities of SCM models such as 4-5 levels of integration, use of IT infrastructure for collaboration at higher levels of integration, etc. which can be incorporated into a construction SCM framework as relevant. The non-construction specific SCM models also showed some aspects that are not relevant to the construction industry. For example, McLaren (2006) pointed out that the concept of a maturity model may not be applicable to some industries due to earlier stages of integration being more cost effective, than the highest stage of integration. This proposition would be applicable to the construction industry due to its short-term project oriented nature. And as Brewer et al. (2007) points out return on investment is a huge concern with short payback periods. Furthermore it was observed that additional measures need to be included in a construction SCM framework, if integration is to be a success. These were included in the section 'CSFs for a SCM framework for the construction industry' (or refer Table 3.3). This was due to measures such as approach to relationships or continuity of works not affecting industries such as the manufacturing industries; hence not included in generic SCM models. In conclusion, this chapter formed the foundation for the proposed framework by establishing the average number of levels of integration for a SCM model and compiling a list of CSFs that are potentially important for the construction industry.

Chapter Four

Research Methodology

Chapter 4 – Research Methodology

4.1 Scope of chapter

This chapter firstly explains the process of research, survey types, ontology, epistemology and methodology in general, and then moves on to explain the rationale for the specific research methods adopted to achieve the goals of this project. The selection of participants, designing of questionnaires, response rates, etc. of each survey and any further relevant literature is explained for each survey conducted for this research in chapters 5 and 6.

4.2 The process of research

Research is explained as a systematic procedure to find the solution to a problem with supporting facts (Leedy, 1989). This research aimed to solve the problem of lack of a framework to measure integration of supply chains in the construction industry, via robust surveys. However, Fellows and Liu (2008) claim that research is a 'voyage of discovery whether anything is discovered or not'. For example, Sarshar et al. in 1999 embarked on a research project to develop a SCM model for the construction industry. However, upon validation of the model it was revealed that the model cannot be applied across supply chain members. Yet the systematic procedure, with supporting facts, to solve the problem has taken place. Fellows and Liu (2008) assert that the degree of discovery will depend on the location and subject of research and the researchers' knowledge, search and analysing techniques. For example, the discovery of the SCM framework in this research is dependent on expertise of construction professionals in the Northern Irish construction industry and the relative novelty of the concept collaboration in the construction industry at this point of time.

Moreover, in addition to claims of Fellows and Liu (2008), this research revealed that the economic climate at the time of surveys will also have an impact on the discovery of research. At the time of embarking on this research in 2006, the UK construction industry was experiencing a boom and the industry was beginning to embrace collaborative forms of practice. Hence the outlook towards this research was positive. However, during the academic years 2009/2010 and 2011/2012 when the Delphi survey in Northern Ireland and the UK wide e-survey were conducted respectively, the UK was experiencing an economic downturn. This had significant impacts on the collaborative ethos in the construction industry, which was in turmoil, due to lack of construction work, reduced employment opportunities, cost-cutting behaviour that focuses on the short-term, etc. Hence the outlook towards SCM became relatively negative during this period, which had an impact on the outcome of this research as explained in the next 2 chapters, particularly chapter 6. The geographical scope of this research was set to one country (the UK - refer chapter 1) because factors such as procurement methods and conflict resolution practices being exercised in various countries affect SCM in different ways.

4.3 The research method

Figure 4.1 captures the research method adopted for this research. The literature review identified the need for the development of a framework for the assessment of integration of construction SCs. Thus a two-step approach of theory building and testing was adopted as depicted in the diagram. The theory building process was conducted via a Delphi survey. The Delphi survey mainly had two consequential goals; firstly, to validate the list of critical success factors (CSFs) compiled via literature (refer Table 3.3), which will be the foundation of the SCM framework, and secondly to develop the complete framework via induction (refer 'output 2' identified in Fig. 4.1). The diagram also demonstrates the adjustments to the database of contacts, after each Delphi iteration, due to attrition of panel members. Thereafter, as shown in Figure 4.1, a questionnaire survey was conducted to test the framework among construction professionals in the UK construction industry. The survey resulted in respondents using the framework to assess their current and future levels of integration, before providing feedback on the ease of use framework, its relevance, etc. Thus this survey, in addition to testing the framework, generated information on the level of integration of construction SCs in the UK. Due to the 'mixed methodology' adopted, encompassing both qualitative and quantitative techniques, it represents methodological rigour according to Tashakkori and Teddlie (2003).

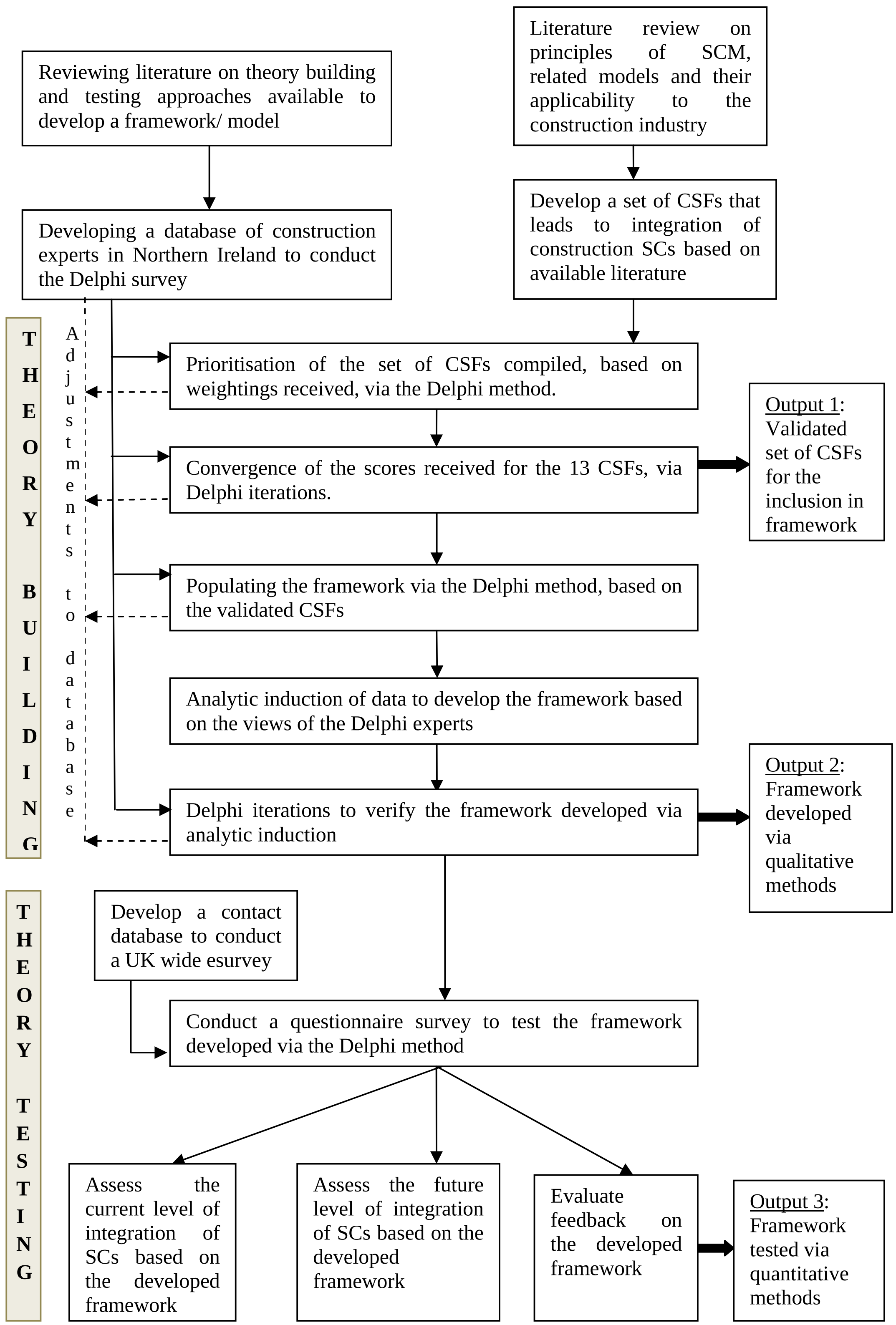

Figure 4.1 – Overview of the research methodology

4.4 Philosophical assumptions

The credibility of research ultimately lies on the philosophical assumptions that underpinned the research (Remenyi et al., 1998; Farquhar, 2012). Hay (2002) states that methodology follows epistemology, and epistemology follows ontology. This is because the researcher's ontological standpoint has an impact on the way he/she will view the world (Farquhar, 2012). Ontology deals with 'different assumptions about whether or not the social world exists independently of our cognitions' and epistemology deals with 'different assumptions about whether or not we can neutrally engage with the social world as researchers' due to knowledge we may or may not be conscious of (Gill and Johnson, 2010, p.211).

The ontology for the first half of the research method, that is the process of developing the SCM framework in this research was ideographic; that is, it was assumed that 'the world is socially constructed and understood only by examining the perceptions of participants or actors' (Farquhar, 2012, p.17). Then the researcher considered the epistemological question 'what must be added to beliefs to convert them into knowledge' (Klein, 1998, 2005; cited in Farquhar, 2012, p.17). Thus this research collated perceptions of construction professionals within a SCM framework of 4 levels of integration and 13 CSFs, via a Delphi survey, where the 13 CSFs and the levels of integration was generated from reviewing literature.

Once the first half of the research method, that is the process of developing the SCM framework, was completed, the research undertook an e-survey which is a deductive approach based on the philosophy of positivism. Two different methodologies being used based on different spectrums of the research onion (refer Fig 4.2) complements this research of methodological triangulation. Punch (2005) claims that this approach of mixed methodologies allows to compensate for weaknesses of each technique.

Positivism is in the outermost 'philosophies' layer of the research onion, and at the left-most end of that layer, aligned with the deductive approach. Positivism 'revolves around discovering patterns in observable events and describing them in the forms of law, with an emphasis on identifying causal relationships and providing explanations. The positivist researcher seeks knowledge phenomena on the basis of measuring and observing' (Collis and Hussey, 2009; cited in Farquhar, 2012). Hence positivists are more inclined to develop and test hypotheses, where the researcher looks to reject his hypothesis according to Popper's hypothetico-deductive method (Farquhar, 2012) which is discussed further in a latter section titled 'Development of a theory'. Thus positivism is the philosophy adopted in this research, which is at the upper-most end of the research onion. The research develops and tests theory based on inductive and deductive approaches. These are the only two approaches available, and the research onion places them at two ends in the layer titled 'approaches'. Inductive approach would be to develop theory and deductive approach is to test theory (see section 4.6 for further details). The research adopts a survey strategy, mixed methods and a cross-sectional time horizon to collect data according to the inner layers of the research onion. Further details of these strategies, choices and time horizons are explained in sections 4.7 and 4.8.

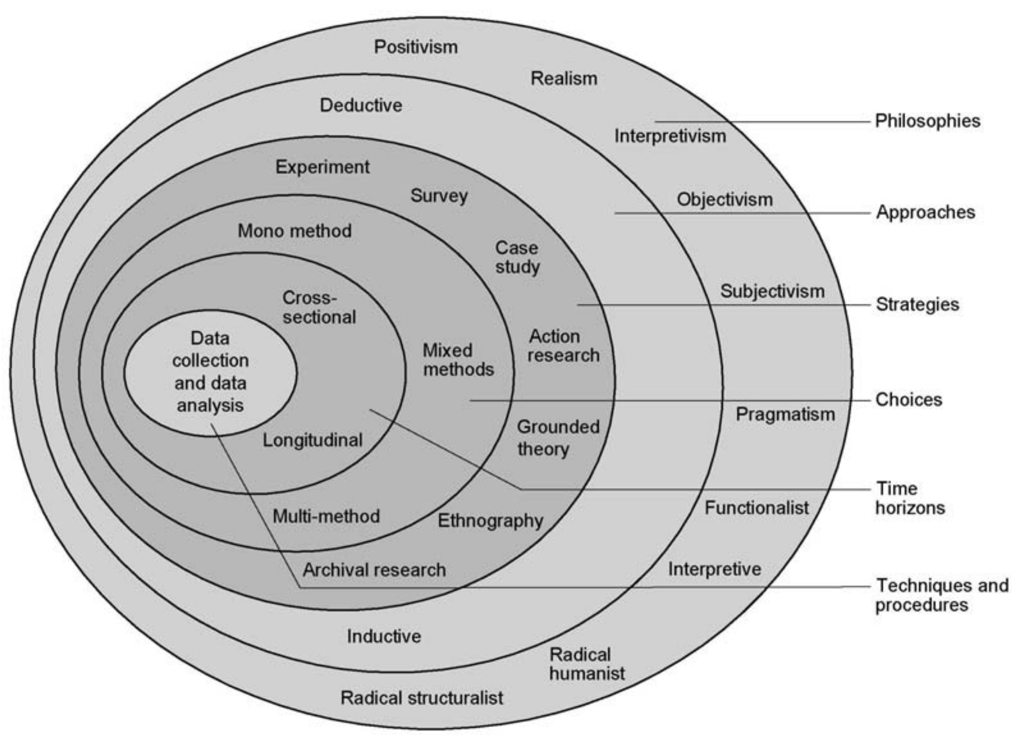

Figure 4.2 - The research onion (Saunders et al., 2007)

Knox (2004) criticises Saunders' research onion as confusing to the research process as it suggests a 'non-rational alignment' between positivism, deduction and quantitative methods, and because it adds an 'opposing alignment' to critical interpretivism, induction and qualitative methods. He emphasises that 'methods are dependent on the research questions, not on one's philosophical stance' and claims that 'if researchers focus on one approach, all of the time, there is a possibility of losing sight of the bigger picture'. It should be mentioned here that he recognises that Saunders did not necessarily suggest this alignment; nevertheless Knox observes that this is how the researchers have interpreted his theory.

4.5 Strategies of research

This research deployed a sequential mixed method, where a qualitative study via a Delphi survey was undertaken to develop the framework, and then a quantitative study via an e-survey, to validate the framework. Qualitative research is very useful for exploration of a new subject, such as SCM in construction, and generation of theory, whereas quantitative approaches adopt a 'scientific method' to test hypotheses generated (Fellows and Liu, 2008). Fellows and Liu (2008) state that quantitative research is more statistically demanding, whilst qualitative research is more intellectually demanding. However, some aspects of qualitative research can be statistically analysed well, as has been done in this research. Since this research is methodologically triangulated it benefits from advantages of both quantitative and qualitative research, listed in Table 4.1. Punch (2005) claims that this approach of mixed methodologies allows to compensate for weaknesses of each technique. For example, close relationships adopted for a qualitative study provides rich and deep data, which can be used to develop theory such as a framework, as done via the Delphi survey in this research; whilst distant relationships provides more hard and reliable data, which can be used to test the theory, as done via the e-survey of this research.

Table 4.1 - Differences between quantitative and qualitative research (Adapted from Bryman, 1998; cited in Naoum, 2007, p.43)

	Qualitative	Quantitative
Role	Attitude measurement based on opinions, views and perceptions measurement	Fact-finding based on evidence or records

	Qualitative	Quantitative
Relationship between researcher and subject	Close	Distant
Scope of findings	Idiographic	Nomothetic
Relatonship between theory and research	Emergent/ development	Testing/ confirmation
Nature of data	Rich and deep	Hard and reliable

4.6 Development of a theory

4.6.1 Theory building

Vaus (2001, p.5) explains that theory building ‘begins with observation and uses inductive reasoning to derive a theory’. Farquhar (2012) illustrates a similar approach to theory building (refer Fig 4.3). It demonstrates that via observing the problem area in concern, you can identify patterns with which you can develop a tentative hypothesis that can be developed into a theory. The term theory is defined by Gill and Johnson (2010, p.43) ‘in its narrowest sense the term theory usually refers to a linguistic framework that is advanced so as to conceptualise and explain the occurrence or non-occurrence, of a particular social or natural phenomenon’. In order to develop theory, in this research observation of SCM experts is gathered via a Delphi survey, which allows the researcher to identify patterns and develop a tentative hypothesis that can be further verified via Delphi experts to develop the theory, which is a SCM framework.

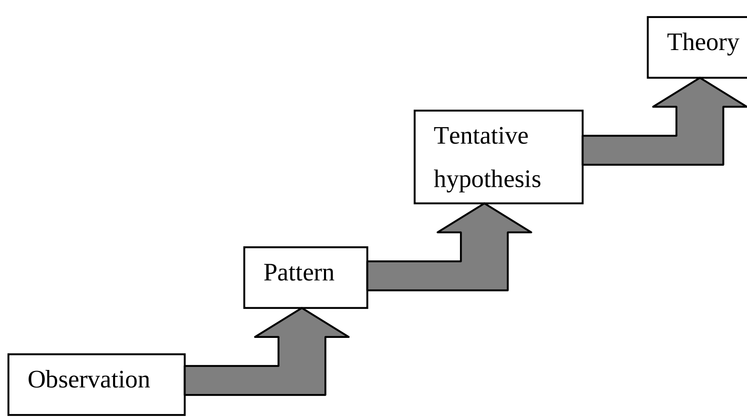

Figure 4.3 - The process of induction for building theory (adapted from Farquhar, 2012, p.24)

Although the process of induction for building theory is agreed in general by researchers, as beginning with observation and ending with a new theory, the point of incorporating literature is not agreed upon. According to Wacker (1998), Goulding (2005), Whetten (1989) and Glaser and Strauss (1967; cited in Knight and Ruddock, 2008) the use of previous literature in theory development is appropriate, even when the research process is inductive. However, each of these authors are not in agreement with regard to how the literature should be used within the theory development process, that is whether the literature review should be used prior to the development of the theory or if it should be used after data collection to see how the new theory fits in within the existing literature. For example, in the context of grounded theory, Glaser's (1978, 1992) interpretations emphasise that there should not be a preconceived theory in mind when developing theory, whilst Strauss and Corbin (1998) express the need for a theoretical statement when developing theory (Farquhar, 2012). Glaser has criticised Strauss and Corbin's approach as making assumptions about data before looking at what the data is actually declaring (Heath and Cowley, 2004; cited in Farquhar, 2012). Cutliffe (2000) reaffirms this divide in approach to incorporation of literature. However most authors (Goulding, 2005; Wacker, 1998; Eisenhardt, 1989; Selden, 2005; Heath and Cowley, 2004; Cutcliffe, 2000; Coffey and Atkinson, 1996; Strauss and Corbin, 1998) cited in Farquhar (2012) argue that literature needs to be incorporated in some way depending on the research approach.

Strauss and Corbin (1998; p.12) have defined grounded theory as 'theory that was derived from data systematically gathered and analysed through the research process'. Glaser and Strauss (1967) have argued that theory that is developed inductively using systematic empirical research is more likely to be accessible, plausible and useful to manage than theory developed from deductive research due to its priori nature (Tenbrunsel et al, 1996; Partington, 2000; cited in Gill and Johnson, 2010).

This research undertook a literature review to identify gaps in SCM research in construction as advocated by Wacker (1998), which gave an idea on what to pursue in this research; that is the development of a SCM framework to assess and improve SCs in the UK construction industry. Further as Goulding (2005) recommends, literature was consulted as part of the data collection process, where initially the initial CSFs derived from literature were surveyed among construction professionals, and thereafter the skeleton of the SCM framework was generated based on previous literature and the survey. The data was then collected and analysed in a systematic manner as advocated in grounded theory, using the Delphi method.

4.6.2 What is a theory?

According to Gill and Johnson (2010, p.43) 'in its narrowest sense the term theory usually refers to a linguistic framework that is advanced so as to conceptualise and explain the occurrence or non-occurrence, of a particular social or natural phenomenon'. They go on to explain that;

1. 'a theory is an abstract conceptual framework which allows us to explain why specific observed regularities happen';
2. 'a theory defines or categorises aspects of the world and relates these phenomena together in terms of cause and effect relationships which explain why what we have observed has actually happened';
3. a theory will usually 'specify situations in which it does, or does not, apply, thereby setting boundaries to where it is applicable as an explanation';

'A conceptual framework explains, either graphically or in narrative form, the main things to be studied – the key factors, constructs or variables – and the presumed relationships among them. Frameworks can be rudimentary or elaborate, theory driven or commonsensical, descriptive or causal' (Miles and Huberman, 1994, p.18).

4.6.3 Theory testing

Farquhar (2012) depicts the process of deduction via Fig 4.4, where the process begins with theory and ends with the confirmation of theory or otherwise, based on observations. Theory testing approach begins with a conceptual theory, such as the SCM framework created using previous literature and a Delphi survey; and consequently uses deductive reasoning to check if the propositions of the theory comply with the observations at an empirical level (Vaus, 2001), such as via a questionnaire survey. The propositions developed to test the SCM framework are listed below.

Proposition 1: Construction professionals find it easy to use the framework.

Proposition 2: The number of levels of integration in the framework is suitable for the construction industry.

Proposition 3: Construction professionals find the framework useful in gauging the level of SC integration in a project.

Proposition 4: The framework indicates how to improve and move on to the next stage of SC integration.

Proposition 5: All sub-sectors of the construction industry can relate to the SCM framework in general.

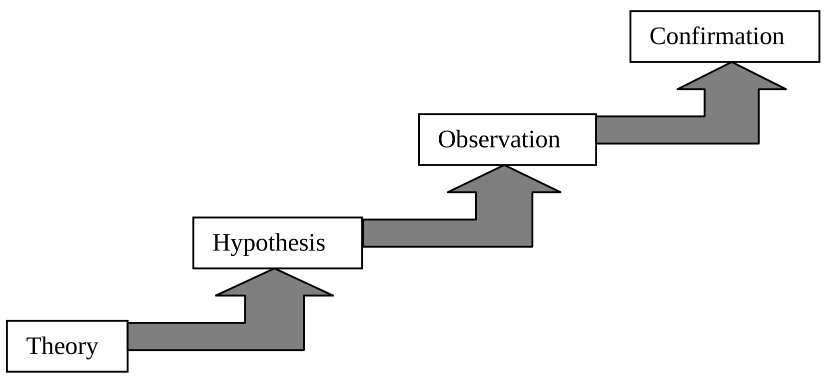

Figure 4.4 - The process of deduction for theory testing (adapted from Farquhar, 2012, p.24)

The experiential learning cycle produced by Kolb et al. (1995) depicts the process of inductive and deductive learning as shown in Fig 4.5. The theory explains that a person could learn inductively by reflecting on experiences, and generate his own concepts. Alternatively, he/she could inherit a concept from another. In either case, this person would apply the learnt concept(s) in new scenarios and test the concept; this process is called deduction. Thus Kolb’s model is closely related to the phenomenon of generating and testing theory, as has been done in this research.

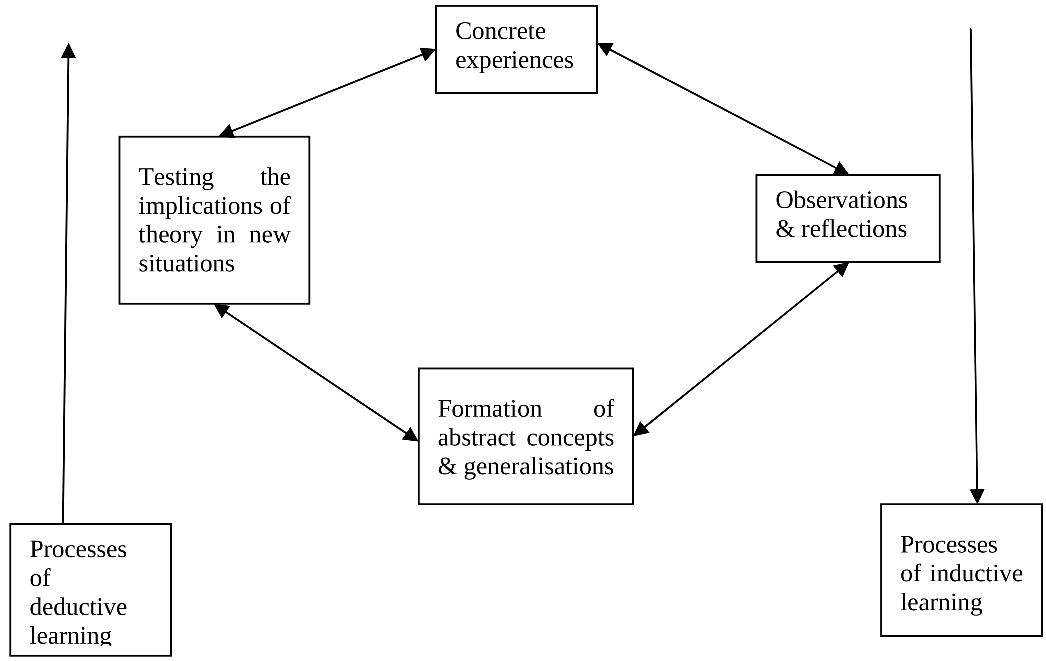

Figure 4.5 – Kolb's experiential learning cycle (Adapted from Kolb et al., 1979, p.38; cited in Kolb et al., 1995, p.49)

However, Popper in his contributions in 1967 and 1972 claim that no theory can be proven by a finite number of observations, as we can never be sure that there is no situation that the theory would not apply to. On this basis Popper criticises Kolb's learning cycle (Gill and Johnson, 2010). Popper, therefore, states that 'theories can never be proven to be true; they can be falsified, since only one contradictory observation is required' (Popper, 1967; cited in Gill and Johnson, 2010, p.53). He then goes on to defining the characteristics of a scientific theory as;

1. 'They must be capable of empirical testing
2. Scientists should not try to find confirming instances of their theories but, rather, should make rigorous attempts at falsifying them using deduction (this is called the hypothetic-deductive method)
3. Science advances as falsified propositions and theories fall away leaving a core of theory which has not, as yet, been disproved and which can be taken to approximate the truth (Popper called this verisimilitude, or truth-like)
4. Theories which have not been falsified can be used to guide practice but we have to be cautious because future observations might disprove them –

therefore such theory driven practice should only be undertaken carefully on a small scale, and continuously evaluated in terms of its affects' (Popper, 1957, pp.44-45; cited in Gill and Johnson, 2010)

Popper claims that the above process detects and removes errors and allows knowledge to grow. The hypothetico-deductive method as proposed by him is presented in Figure 4.6, as cited in Gill and Johnson (2010). This approach is categorised under positivist philosophy, as is most scientific research.

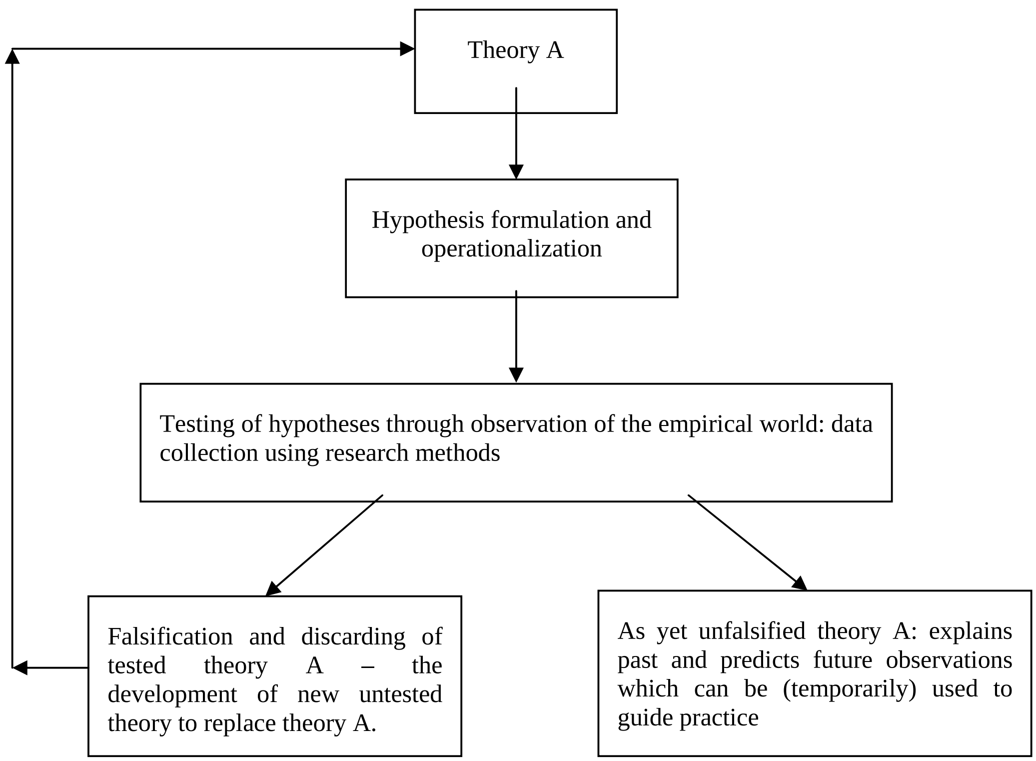

Figure 4.6 - The hypothetico-deductive method (Gill and Johnson, 2010, p.54)

Gill and Johnson (2010) recognise that a developed theory may need to be 'operationalised' in order to be tested (refer Fig. 4.6), as some abstract concepts do not lend themselves to be empirically tested without being translated into specific observables. Thus in this research the developed framework is firstly operationalised via respondents using the framework. Thereafter the propositions are tested in order to accept or reject the developed framework. Hence in addition to evaluating the framework, the research will generate some useful data regarding the outcome of using the framework by different construction organisations.

4.7 The Delphi method

Causal relationships are difficult to establish because it is difficult to examine an observable fact producing change in another. Therefore causal relationships must be inferred rather than observed (Vaus, 2001). Hence this research adopted the Delphi technique to obtain inferences regarding supply chain collaboration from construction experts. Their inferences would be based on 'on-the-job' observations made during their career and use of inductive reasoning to derive a theory from these observations. In comparison to inductive case studies, the Delphi method will provide access to more scenarios due to its approach of contacting 10 – 50 professionals. This would be beneficial towards developing a more generalised SCM framework. A common problem in previous research (O'Brien et al., 2002; Ebrahimy et al., 2011) is that construction SCM related research has been based on case studies which makes it difficult to apply to the construction industry in general. Similarly the use of focus groups for theory development would have restricted the number of professionals involved (due to logistical issues), number of iterations (due to appointment clashes) and forfeited the anonymity of respondents (leading to biased responses). Hence it was concluded that the Delphi method was more suitable for this qualitative stage of the survey than case studies or focus groups.

The Delphi method is also very useful in forecasting. The need to forecast is necessary to develop the higher levels of integration for a SCM framework for the construction industry. Humans have the capacity to forecast issues, hence research in the built environment increasingly use the Delphi technique (Ratcliffe, 2008). He explains that when these perspectives are held by multiple people the thoughts appear as divergent. However, when a researcher collates data and finds patterns in them, emergent theories occur in terms of frameworks and structures. Thereafter, further research can be done to reduce data, which is referred to as convergence. 'Data reduction is a form of analysis that sharpens, sorts, focuses, discards, and organises data in such a way that final conclusions can be drawn and verified (Miles and Huberman, 1994, p.11). The transcripts, extracts and abstracts created to develop the SCM framework in this research are included in Appendices 14 – 16 and are further explained in chapter 5.

4.7.1 The background of the Delphi method

The Delphi method first emerged in the 1950s, as part of a US sponsored military project. Since then this method has been widely used by various industries including health care, defence, business, education, information technology, transportation and engineering (Skulmoski et al., 2007). Rowe and Wright (1999) explain that the Classical Delphi method is characterized by the following four features.

1. Annonymity of respondents – All respondents of a classical Delphi survey remain anonymous throughout. This eliminates the pressure of group conformity, and encourages the expressing of independent opinion of individual experts.
2. Controlled feedback – The opportunity for respondents of survey to be informed of other participants' (annonymised) responses, and amend one's views if deemed appropriate to them.
3. Iteration – The opportunity for respondents to reflect on their expert opinions, and refine their views when progressing from round to round.
4. Statistical group response – The method allows for reaching consensus, and offers a statistically accepted solution.

To encourage individual expert opinion being expressed, without the pressure of group dynamics, the Delphi technique administers questionnaires via post or email rather than using face to face sessions (Manoliadis et al., 2006). Thus this research conducted its Delphi survey by distributing questionnaires via email. Since communication is an important factor in SCM, it was considered that any SCM expert in the construction industry should have an email account. The Delphi method was selected for this research over focus groups, due to the advantage of the anonymity of respondents in the Delphi method. It also allowed a number of iterations to take place when conducting the Delphi survey, which would have been much more difficult if experts were to attend a number of focus group sessions. The Delphi method also allowed the views of 48 experts to be included in the survey, which would have been limited to 6-12 if it were focus groups.

The number of participants for a Delphi survey is contested widely, as the following table 4.2 compiled from literature demonstrates. The authors who favour a lower number in the panel argue that the Delphi technique is not looking for statistical power, but achieving consensus, which would be difficult to attain with a larger panel size. However, early researchers on the method, such as Linstone and Turroff (1975) recommend a much larger sample such as 10-50 experts. It should be noted that Dalkey (1969) explains that the degree of truth in a speculated answer of a respondent increases with the expertise of the respondent. Hence the more important aspect of the panel is the expertise of the panel, rather than the number of experts. Thus criteria for panel selection become important, which is explained under section 4.7.2. The expertise of each category of respondent and their response rates for this research are discussed in chapter 5. Linstone et al. (1975) claims that a 45%-50% response rate is sufficient for a Delphi survey, and that reduction of respondents when conducting Delphi iterations is inevitable. It should be noted that Moser and Kaltan (1971) said that surveys with response rates lower than 30-40% are biased. However, recent researchers (Curtin et al., 2000; Goves, 2002; Gill and Johnson, 2010) revoke this statement (see 4.8.3). Lower response rates are to be expected in Delphi surveys, due to consecutive iterative rounds which continue to contact the same set of respondents. Witkin and Altschuld (1995) state that poor response rates are magnified fourfold in the Delphi method due to four surveys being sent to the same panellists. Thus this research will focus on gaining, at least, the minimum number of responses as recommended for the Delphi panels (see Table 4.2).

Table 4.2 - Number of participants for a Delphi survey

Researchers	**Size of Delphi panel recommended**
Rowe and Wright, 1999; Adnan and Morledge, 2003	3 - 15
Okoli and Pawlowski, 2004	10 – 18
Rowe (1998)	35 – 39
Linstone and Turoff (1975)	10 – 50
Gibson and Miller (1990)	An initial list of 60 members should produce 20 or 30 actual participants.

Pilot for Round 1a
A panel of 5 experts responded with regard to the length and clarity of questionnaire. (Refer 5.3.1)

↓

Round 1a (R1a)
31 experts responded to the questionnaire, where they scored the level of importance of the 13 CSFs. (Refer 5.3.2)

↓

Analysis of R1a
The mean and inter-quartile range of each factor was calculated, and checked for convergence. (Refer section 5.5.1)

↓

Round 1b (R1b)
The 31 respondents of R1a was given feedback with regard to group results, and provided opportunity to revise their previous scores, if desired. (Refer 5.5.2)

↓

Analysis of R1b
Revised scores were analysed, and the results converged for all 13 CSFs. (Refer 5.5.3)

↓

Pilot for Round 2a
The 5 pilot experts responded with regard to the length and clarity of questionnaire. (Refer 5.8.2)

↓

Round 2a (R2a)
The panellists were requested to describe the 13 CSFs based on 4 levels of integration. (Refer 5.8.3)

↓

Analysis of R2a
Analytic induction was carried out to develop the framework based on responses. (Refer 5.8.4)

↓

Round 2b (R2b)
The respondents to R2a were provided feedback with regard to the developed model, and gave an opportunity for them to make any changes, if desired. (Refer 5.8.5)

↓

Analysis of R2b
The responses were analysed and the survey was concluded at this stage (Refer 5.8.5). The developed framework is presented in 5.9.

Figure 4.7 – Sequential process of the Delphi method adopted for the research

Gibson and Miller (1990) give a more practical insight to the number of panel members where they recommend starting with a list of 60 which would produce 20-30 actual participants. Attrition of panel members is a reality in conducting a Delphi survey, particularly when there are several rounds involved. For the purposes of this research an initial list of 67 potential participants were contacted, where 31 responded for the first round and 13 remained by the final round. The final round still consisted of a number of participants which is higher than the minimum expected from most researchers. Further statistics of the Delphi rounds conducted are discussed in chapter 5. The steps of the Delphi survey is included below in a flow chart.

4.7.2 Panel selection, attrition and conditioning

Panel selection

Chan et al. (2001) states that selection of the Delphi panel should be carefully done, because the success of the method depends on the panel. This statement is further validated by the pioneer of the Delphi method, Norman Crolee Dalkey (1969) who claims that the responses of a Delphi survey is dependent upon the expertise of the Delphi panel about the subject being forecasted. Hence this research adopted the following criteria, as recommended by Yeung et al. (2009) for a survey in partnering in the Hong Kong construction industry, when selecting the Delphi panel. The list of respondents is included in Appendix 1.

1. They have at least more than 5 years of experience in working in the construction industry.
2. They are currently involved in dealing with SC members.
3. They have an understanding of the concept SCM/ collaboration in the construction industry.

It should be noted here that the nature of the topic of this research does not allow more stringent criteria, such as membership in a SCM institute, an SCM related degree, 20 years of experience in the construction industry, etc. SCM is still a relatively new concept in the construction industry. Hence related qualifications or membership is unheard of within the industry. Moreover, involvement in SCM is not dependent upon the number of years of construction experience, but on the attitude towards collaborative ethos of the respondent and his/her organisation. For example a construction professional with 20 years of experience may be reluctant to change, whilst a construction professional with 5 years of experience may be more enthusiastic about benefits attainable from SCM. Hence the criteria suggested by Yeung et al. (2009) were deemed relevant for this research.

Panel attrition

Attrition is a reality in any survey, however as Vaus (2001) explains when a survey consists of several iterations the rate of attrition is far greater. However, as was observed during the conducting of the Delphi survey, the ‘drop outs’ were mostly the respondents who identified themselves to be somewhat lacking in SCM expertise. For example in the initial round of the Delphi survey of this research some small consultancy firms declined to respond due to lack of expertise, and the contractors who rated themselves highest with regard to level of expertise, responded the most to all iterations. Further statistics in this regard are available in chapter 5. As Dalkey (1969) explains this is acceptable in a Delphi survey because the ability of a respondent to speculate the correct answer increases with their level of expertise.

Panel conditioning

Another problem many researchers face is the issue of panel conditioning, typically when conducting longitudinal research. If the panel become more aware of the issue discussed over time, generalisation of the results can be questionable as Vaus (2001) explains. For example, completing round 1a of the Delphi survey sensitizes the participants to SCM issues, and would probably make them more thoughtful of the issues in their everyday lives. Vaus continues to explain that this is more problematic in descriptive research than exploratory research because effects on behaviour or attitudes would affect the survey, but conditioning (being more alert to SCM issues) should not affect the way factors are linked with each other. Hence it can be concluded that this effect (panel conditioning) improved the expertise of the Delphi participants per iteration, which allowed the participants to become more confident in responding to the detailed survey of Round 2. Thus panel conditioning in fact is an advantage for a Delphi survey such as the one conducted for this research.

4.7.3 Analysis for consensus in Delphi studies

Hasson et al. (2000) state that measures of central tendency (mean, median and mode) and level of dispersion (standard deviation and inter-quartile range) are the main statistics used to demonstrate the collective judgement of Delphi panels, where the use of mean and median are the most favoured (Keeney et al., 2011). Skulmoski et al. (2007) recommend the use of mean and Kendall's W for calculating degree of consensus. However, Witkin (1984) criticises the use of the mean in Delphi studies, particularly when scales used in the research is not delineated at equal intervals. Jacobs (1996, p.57) states, "considering the anticipated consensus of opinion and the skewed expectation of responses as they were compiled, the median would inherently appear best suited to reflect the resultant convergence of opinion" (Hsu and Sandford, 2007). Thus Keeny states that the use of median is the most favoured in literature. However, Ludwig (1994) explain that sometimes the results could cluster around two or more points, in which case neither the use of median or mean would be accurate. Hence the use of mode is recommended (Hsu and Sandford, 2007). Thus there is much dispute about the use of different statistics in Delphi. Yeung et al. (2007) and Yeung et al. (2009) have used the mean in construction SCM related Delphi studies in Hong Kong and Australia. Verhagen et al. (1998) explain that consensus studies such as Delphi are useful in combining knowledge and experience of industry experts when information available in an area is limited, and have adopted the mean the as the main statistic to combine the judgement. Thus in this research the mean was adopted to measure the central tendency and the inter-quartile range provided as a measure of dispersion.

4.7.4 Factor analysis

Factor analysis can be conducted using SPSS software to find out if the 13 CSFs could be categorised in to a fewer number of success factors. Comrey (1973; cited in Stevens, 2009) suggests as a guideline for orthogonal factor interpretation: 0.71 as excellent, 0.63 as very good, 0.55 as good, 0.45 as fair and 0.32 as poor. Hence factor loadings less than 0.45 is normally discarded in such exercises. Stevens (2009) state that it is widely accepted that larger sample sizes increase the generalisability of the conclusions. Yet Dalkey (1969) claimed that the degree of truth in a response increases with the expertise of the respondent. Thus sometimes the ability to generalise and the level of truth in a response could be in negation, particularly in research areas such as construction SCM due to the lack of a large sample of experts in SCM.

4.8 The questionnaire survey

This research conducted a questionnaire survey to test the theory generated via the Delphi method. According to Simons (1987) questionnaire surveys, particularly analytic surveys are a useful tool in testing theory. Gill and Johnson (2010) state that operationalising an abstract concept using observable indicators results in a tested theory. He further explains that once the theory is tested and corroborated, the theory is established, within the deductive tradition. Thus the questionnaire survey was the mechanism used to ‘operationalise’ the SCM framework within UK via professional opinion of the construction industry. It should be noted here that deductive case studies was also usable in testing theory. However, as explained in section 4.7 due to the limitation of case studies, a questionnaire survey was selected for the research to allow generalisation of results.

4.8.1 Sampling

Random sampling is important when conducting a questionnaire survey. However, when there are different sub-groups within a population, random sampling from the entire population or sample is not acceptable. In such situations an alternative strategy called stratified sampling should be conducted (Gill and Johnson, 2010). Hence random sampling from the entire population of construction professionals was not appropriate due to the variety of sub-groups available within the construction industry, such as contractors, consultants, suppliers, etc. The same categories identified for the Delphi method were selected for the questionnaire survey as well (further explained in chapter 5 and 6). Hence random sampling within sub-groups, that is stratified sampling was carried out.

4.8.2 Sample size

G* Power software suggested that a total of 179 responses need to be collected to allow ANOVA F tests to be conducted. This was with the aim of finding correlations among the 4 categories of SC members, at 80% power and 95% confidence level. This suggests a sample of 45 per category. Bartlett et al. (2001) state that many researchers increase this value by 50% to allow for non-respondents, although this method has the potential to increase non-response bias (Gill and Johnson, 2010). This would mean that the sample size needs to be increased to 90 per category. However, this may be difficult for a survey on SCM to achieve in the construction industry, due to perceived lack of involvement in SCs by construction professionals. It should be noted that although most research in SCM in the manufacturing industries are quantitative (Kotzab et al., 2005) all research regarding core issues in SCM, in the construction industry, has been qualitative (Ebrahimy et al., 2011). Thus in order to substantiate research in the construction industry with quantitative research, a survey among 360 professionals will be conducted. Yet it should be noted that if 179 responses are not received, correlations with regard to difference in sub-sectors of the industry cannot be established. However it would allow the framework to be tested quantitatively, and would provide some insight to SCM practices in the construction industry in general (due to quantitative results), rather than through selected case studies which prevents generalisation of results. Furthermore the research would benefit from methodological triangulation due to the proposed SCM framework being supported via qualitative and quantitative surveys.

4.8.3 Response rate and response bias

This research assumed a 50% response rate to calculate the number of contacts, based on Gill and Johnson (2010) as explained in 4.8.2. Moser and Kaltan (1971) state that a survey requires a response rate over 30-40% to reduce bias. Yet in more recent times Curtin et al. (2000) found out that the impact of response bias increases with large sample sizes although sample error declines in large samples. However, Groves (2002) has established that there is no response rate below which it can be identified as leading to non-response bias. Similarly that there is no response rate above which might indicate non-response bias. Gill and Johnson (2010) similarly argue that it is best to analyse respondents and non-respondents of a survey, rather than attempting to increase the response rate in the hope of reducing response bias. It was also noted that SCM related surveys generate low response rates such as 11% (Basnet et al, 2003), 21% (Simatupang and Sridharan, 2005), 25% (Akintoye and Main, 2007). This may possibly be due to the complexity of the subject, its relative novelty to the industry or less practicing of SCM during economic downturn.

4.8.4 Creating the sample of contacts

The scope of this research was the UK, as the framework developed is intended for the construction industry in the UK. Hence the questionnaire survey was decided to be conducted in the UK via an e-survey tool. The e-survey tool allowed the creation of mail lists for the four categories separately; namely clients, consultants, contractors and suppliers. Respondents' contact details were obtained from various websites such as the CIOB, RICS, RIBA, APM, Considerate constructors' scheme, Top 100 construction companies' website leading to individual company websites, local councils who get involved in construction projects, Construction employers federation, business magnet.co.uk, etc. All relevant organisations from these websites were selected due to expected low response rate, attributable to lack of professionals actively involved in SCM in the construction industry. It should be noted that most research carried out regarding SCM in the construction industry is qualitative (Ebrahimy et al., 2011). This is probably because of the lack of response from professionals with limited exposure to SCM principles, as observed in the Delphi survey. The few quantitative research conducted had been based on a number of a simulations within a single project as done by Ebrahimy et al. (2011). This is quite different to the manufacturing industries where most of their SCM research is quantitative rather than qualitative (Kotzab et al., 2005).

4.9 Summary of chapter

The chapter explained the philosophical assumptions in research, process and strategies of research and moved onto discussing the process of developing a theory, such as a SCM framework for the construction industry. It was revealed that induction is commonly used to build theory, typically via a qualitative method; and a process of deduction to test theory, typically via a quantitative strategy. Different approaches in these methods were examined in the voyage to justifying a methodology for the development of the SCM framework. The Delphi method, which was used to build the theory, was explained in detail in section 4.6 and the background to the questionnaire survey to test the theory was set out in section 4.7. Further details of each of the methods are discussed in chapters 5 and 6.

Chapter Five

Development of a SCM framework for the construction industry via the Delphi method

Chapter 5 – Development of a SCM framework for the construction industry via the Delphi method

5.1 *Scope of chapter*

This chapter discusses the four Delphi rounds, namely Round 1a, 1b, 2a and 2b, which were conducted with the aim of developing the 13 CSFs (Critical Success Factors) compiled in chapter 3 to a SCM framework. The survey was conducted during 2009 - 2010 among construction professionals in Northern Ireland. The chapter explains the number of participants, attrition of participants over time, the pilot surveys, the questionnaires, the iterations, data collected and its analysis and discussion. The rationale for the Delphi survey, background of the Delphi technique, etc. are explained in the previous chapter on research methodology (chapter 4). The framework produced via the Delphi method is available at the end of the chapter (refer Table 5.).

5.2 *Selection of participants for the Delphi survey*

An initial database of 63 experts from the Northern Irish construction industry was created, via several brainstorm sessions with three senior academics at University of Ulster, based on their experiences of collaborating with construction organisations regarding SCM matters. This selection method has also been adopted by Verhagen et al. (1998) in their Delphi studies. This approach is supported in Delphi because Dalkey (1969) explains that the crucial element in the survey is the expertise of the panel as explained in chapter 4; not random selection or a high number of participants. Clayton (1997, p.380) explains that 'Expertise exists in various forms and, although it may be difficult to measure exactly, there are general characteristics of individuals who, in a given context, demonstrate a level of wisdom, insight, theory, practice, experience and analysis not found common to all individuals. It is these individuals to whom the term 'expert' is assigned. It is reasonable, therefore, to seek out individuals whose peers regard them in this light.' It took 3-4 months to vet the experts and complete the database consisting of 4 categories within the construction industry; namely Client, Consultant (including PMs, architects, QSs and engineers), Main contractor and Sub-contractor/ Supplier.

Table 5.1 - Categories of experts for the Delphi survey

Classification	Category	Sub-categories
Tier 1: Demand side	Clients	Public & Private sector clients
Tier 2: Design side	Consultants	Project managers, Quantity Surveyors, Engineers & Architects
Tier 3: Implementation side	Main contractors	Main contractors; subdivided as large firms & SMEs, based on publicly available data.
Tier 4: Supply side	Suppliers	Trade and specialist subcontractors & Material and plant suppliers.

Table 5.1 further defines the categories of experts selected for the Delphi survey, encompassing the main participants of a construction SC. Every attempt was taken to have an equal number of participants of every category, and an equal subdivision among sub-categories throughout the survey. The following criteria were adhered to when selecting participants, as advocated by Yeung et al (2009).

1. They have at least more than 5 years of experience in working in the construction industry.
2. They are currently involved in dealing with SC members.
3. They have an understanding of the concept SCM/ collaboration in the construction industry.

As explained in chapter 4, the most important issue to deal with when conducting the Delphi method is in getting 'experts' in the relevant area involved in the survey. Recommendations of senior academics at University of Ulster, in relevant professional areas, were taken on board when creating the database. Then upon contacting the recommended contacts firstly via telephone, the above listed criteria were verified during conversations with regard to their confidence in getting involved in this survey and via their curriculum vitas. Thereafter, the Round 1a questionnaire included questions with regard to their expertise in SCM and requesting them to explain SCM within the context of the construction industry. The construction of this questionnaire is further explained in the following section.

5.3 *The construction of the Round 1a questionnaire*

The questionnaires were kept relatively straightforward to discourage attrition in iterative Delphi rounds as much as possible. The questionnaire and the cover letter are available in Appendix 4. The questionnaire was arranged into 3 sections as follows:

Section 1: Page 1 – General information

Section 1 of the questionnaire aimed to gather data such as the type of organisation and designation of participant and sought to further establish the expertise of the participant. Participants were asked to explain supply chain integration within the context of construction, were questioned on their understanding of benefits of SCM in the construction industry and also to gauge themselves on their level of expertise in SCM. The ability to answer open-ended questions on SCM further established the thorough selection of appropriate participants for the Delphi survey, as emphasised as crucial to the process of Delphi iterations by Chan et al. (2001).

Section 2: Page 2 – Assessment of factors leading towards integrated construction supply chains.

This section listed 13 CSFs that the Delphi participants were asked to score based on their perceived degree of importance of the CSFs. The list of CSFs was compiled using previous literature within the context of the construction industry. The list was further verified through discussions with three senior academics prior to dissemination among the participants of the Delphi survey. The CSFs were scored on a 6-point Likert scale based on their degree of importance as shown in Table 5.2.

Table 5.2 - Likert scale for measuring importance of CSFs

0	**1**	**2**	**3**	**4**	**5**
Not at all important	Slightly important	Moderately important	Important	Very important	Extremely important

Additional rows were provided at the end of the 13 CSFs to add any further CSFs, if the experts deem it necessary. None of the main contractors, subcontractors or suppliers added further CSFs to the list provided. However, six respondents (three consultants and three clients) suggested 11 factors to be added to the list. They were more narrow and specific in nature such as 'outmoded information' which can be considered as encompassed under the factor extent of communication between SC members or use of IT for collaboration, where outmoded information will be a measure in existence at lower levels of integration. Hence these factors could not be considered to be added to the list of 13 CSFs as they were already covered within the 13 CSFs. Another example of a suggestion is 'good personal relationships' which can be classified under factors such as 'positive attitude and approach to working relationships' or 'extent of communication between SC members', where good personal relationships will occur at higher levels of integration. The classification of all these suggested factors is included in Appendix 6 and discussed in section 5.5.1. Due to the reasons discussed above and due to this framework being expected to be at the strategic/managerial level rather than at the operational/ tactical level, none of the suggested factors were added onto the list of CSFs.

Section 3: Page 3 – Assessment of factors expected from integrated construction supply chains.

The section listed 13 benefits expected from collaboration in the construction industry, supported from previous literature discussed in chapter 2. These factors were asked to be scored on the degree of expectation, on a 6 point Likert scale as shown in Table 5.3:

Table 5.3 - Likert scale for measuring expectation of benefits from SCM

0	**1**	**2**	**3**	**4**	**5**
Not at all expected	Slightly expected	Moderately expected	Expected	Very much expected	Extremely expected

Participants were given an opportunity to suggest additional factors to this list as well. The factors suggested, and how they have been classified into the initial list of benefits is demonstrated in Appendix 6. However it should be noted that this section was not further built upon within iterative Delhi rounds, as there was no intention of including aligned benefits in the SCM framework to be developed. The purpose of the section 'Competitive advantages expected from integrated SCs' is to help respondents differentiate between factors leading *from* and factors leading *to* integrated SCs. This requirement to develop the respondents' understanding, through reflection of their own experience and knowledge of SCs, was observed during pre-pilot studies. The importance of distinguishing between these 2 sets was discussed in chapter 3.

The Round 1 questionnaires were also a precursor for the Round 2 questionnaires which expects respondents to populate a SCM framework for the construction industry. In a pre-pilot study it was found that even construction 'experts' struggle to populate the SCM framework when it's given as the first task. However when they are allowed to 'warm up' to the topic by discussing applications of SCM in their construction organisation and then the importance of factors leading towards SCM they were able to populate the SCM framework confidently. The researcher interprets this phenomenon as respondents implicit knowledge of SCM is made more explicit from the questions asked in the questionnaire of Round 1. Further due to attrition of selected experts in Round 1, more able respondents are naturally selected for Round 2 of the survey.

Hence the main purpose of this section was to help participants of the survey clearly differentiate between the benefits derived from integrated supply chains and the success factors leading towards integration of supply chains. It should be reminded that SCM or collaboration in the construction industry is still a relatively new concept. Hence most construction professionals would not have received structured training on the concept. Thus section 3 of the questionnaire helped put SCM into context for the participants.

5.3.1 The pilot survey

It was decided that a pilot survey among an expert panel of 6 construction stakeholders representing consultant, main contractor, sub-contractor, material supplier, public sector client and private sector client will be conducted before each Delphi round. The questionnaire (see appendices 2 and 3) was tested for clarity, ease of understanding, time taken to respond, etc. Five out of the six experts (except the private sector client) responded to the questionnaire, within 3 weeks of receiving the questionnaire, with responses ranging from good – very good for the questionnaire's clarity, simplicity, etc. These 5 pilot experts (consultant, contractor, sub-contractor, material supplier and public sector client) were contacted prior to each of the subsequent Delphi iterations.

It should be noted though that pre-pilot studies were conducted, prior to the pilot survey explained above, among construction professionals known to the researcher to develop the questionnaires to a level which will be found easy, clear, etc. The necessity for Round 1 and 2 to be separated was understood from pre-pilot studies. As explained in detail earlier, due to SCM knowledge in the construction industry still being more implicit rather than explicit, it becomes necessary for the researcher to conduct the survey in an incremental manner to allow the Delphi participants to become confident over time in populating a framework for construction SCs.

5.3.2 Conducting Delphi Round 1a

Round 1a was conducted over a period of 7 weeks from January to March in 2010 via email. However respondents were contacted through telephone first of all to brief them on the survey and gain their consent to participating in the survey. The initial database of 63 experts was contacted, and upon receiving consent, they were emailed the Round 1a questionnaire. This process took 2-3 weeks. At this stage some of the participants who agreed to respond to the survey have declined due to the complexity of the subject. This was not considered a set-back as the expertise of respondents is more important than the number of respondents of a Delphi survey according to Chan et al. (2001).

One set of reminder emails were sent after one month of starting the survey. Few new experts were added to the database at this stage to balance the number of responses among the categories client, consultant, contractor and supplier. This increased the number of total contacts in the database to 67 experts.

After 7 weeks of starting the survey, 31 responses were received. This represents a response rate of 46.3%. Given the novelty of the subject area, SCM in construction, this response rate was deemed satisfactory. The Round 1a survey was concluded at this stage. It should be noted that according to RAND experiments over a number of 29 experts does not really add to survey results (Dalkey, 1969). He argues that the decrease of group error, with the increase of participants in a group becomes marginal over the limit of 29 participants. Moreover, Gibson and Miller (1990) state that it is appropriate to have 20-30 participants in a Delphi survey, where a database of 60 experts are contacted. Linstone and Turoff (1975) have recommended a panel with a minimum of 10 and a maximum of 50. However Rowe (1998) argues that no significant effects are linked to group size. Researchers such as Rowe and Wright (1999) and Adnan & Morledge (2003) state that participants for a Delphi survey should range between 3 - 15. Further literature on Delphi surveys is discussed in the previous chapter. Hence 31 responses were considered sufficient for a Delphi survey.

5.4 *Analysis of the composition of Round 1a respondents and their level of expertise*

Two respondents out of 31 respondents had not answered one factor each. This means that 24 out of 26 factors tested have 31 responses each, and 2 out of 26 factors have 30 responses each. Further analysis of the responses received for Round 1a is presented in Table 5.4.

Table 5.4 - Number of responses received and response rates for Round 1a

Category	Number contacted	Number responded	Response rate	Remarks
Clients (Tier	15	8	53%	Five public sector clients

Category	Number contacted	Number responded	Response rate	Remarks
1)				and three private sector clients responded.
Contractors (Tier 3)	17	8	47%	Out of the 8 responses, 7 were from large contractors and 1 from a medium sized contractor, despite being contacted in equal amounts. There were no responses from small or micro organisations.
Consultants (Tier 2)	20	9	45%	Architects, Civil & structural engineers, QSs and M & E consultants were consulted in equal amounts. One architect and one civil engineer claimed that they lacked SCM experience and expertise to respond to the questionnaire due to belonging to a small consultancy practice. None of the M&E consultants contacted responded, even after persuasion. Hence another sub-category for project managers were included and contacted. Finally 3 QSs, 2 architects, 3 civil and structural engineers and 1 project

Category	Number contacted	Number responded	Response rate	Remarks
				manager responded.
Suppliers & Subcontractors (Tier 4)	15	6	40%	Three from each category responded.
Total	**67**	**31**	**46%**	

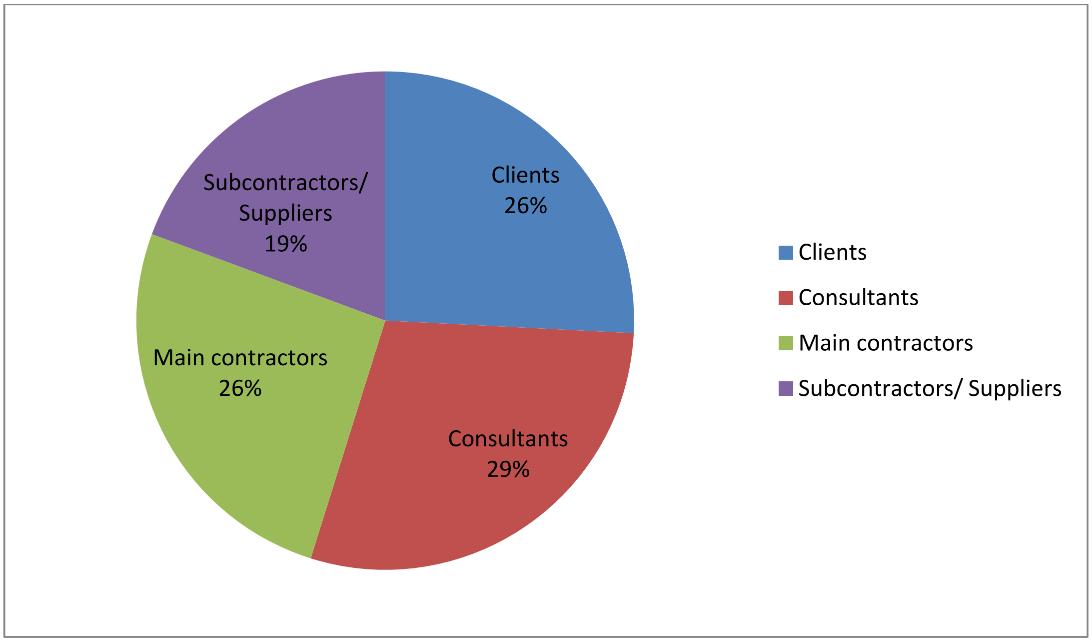

Figure 5.1 - Composition of categories of respondents for Round 1a

Response rates are higher at the client end of the supply chain rather than at the supplier end of the supply chain. It is not clear if this is due to their high interest in SCM or their high level of expertise in SCM. Based on the clients' assessment of their level of expertise in SCM, it is 3.25 out of 5, which places the clients behind contractors and consultants who scored 4.00 and 3.33 respectively. Hence it is probably the clients' high interest level in SCM, rather than their level of expertise that has led to a high response rate. It should be noted that some public sector organisations have an obligation to respond to all emails. This would have had some effect on the high response rates of the public sector clients. Clients submitted the highest number of responses in Round 2a as well, as can be seen from Table 5.5.

Table 5.5 - Number of responses in comparison with level of expertise in SCM

Category of respondents	**Number contacted**	**R1- No. of responses**	**Average score of expertise**	**R2- No. of total responses**	**R2- No. of usable responses**
Suppliers and subcontractors (Tier 4)	15	6	3.17	1	0
Client (Tier 1)	15	8	3.25	6	5
Consultant (Tier 2)	20	9	3.33	3	3
Contractors (Tier 3)	17	8	4.00	5	5

Table 5.6 - Likert scale for measuring level of SCM expertise of respondents to Delphi survey

1	**2**	**3**	**4**	**5**
Poor	Satisfactory	Good	Very good	Excellent

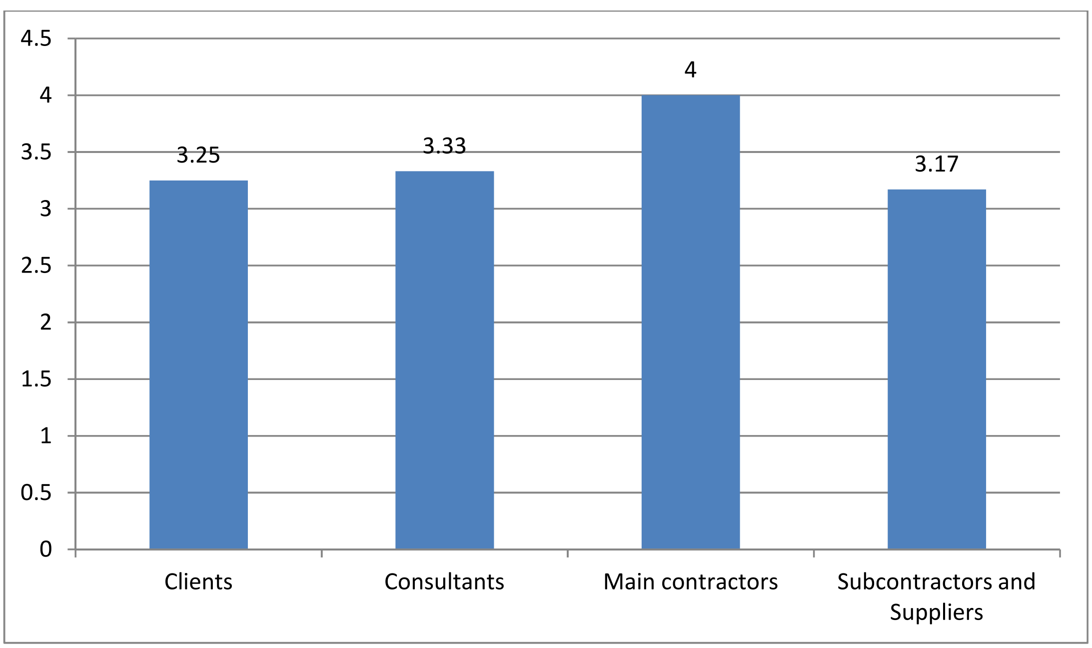

Figure 5.2 - Level of SCM expertise based on respondents' categories

It is the contractors who rated themselves highest as experts in SCM, and they generated the second highest response rate in Round 1a and submitted the highest number of usable and relevant responses in Round 2a, alongside clients. However, it should be noted that although contractors of various sizes were invited to respond to the survey, it is only large organisations (and one medium sized organisation) that responded to the survey. SCM is not a concept that is well understood or applied in smaller organisations in the construction industry yet. This phenomenon is further accentuated in consultants' responses, where a few declined to respond to the questionnaire due to lack of experience in SCM, which they attributed to belonging to a 'small consultancy practice'.

Subcontractors/ Suppliers assessed themselves as having the lowest level of expertise in SCM and produced the lowest number of responses and response rates for all Delphi 4 rounds. It appears therefore that as claimed they do not have sufficient expertise to complete the questionnaire. Hence the measurement of the level of expertise via their own perception can be relied upon as a reliable measure of the participants' expertise in SCM.

5.5 *Verification of critical success factors leading to an integrated construction supply chain*

5.5.1 Analysis of Round 1a results

The average, lower quartile and upper quartile mean functions of MS Excel were used to analyse the data received from Delphi Round 1a. Inter-quartile range was then computed to establish if the factors were reaching consensus, as required for the Delphi method (refer section 4.7.3). Nine out of the 13 CSFs leading towards integrated SCs reached consensus in round 1a, i.e. they generated an inter-quartile range of l1l or less. These 9 factors generated a mean of more than 3.0, which indicates that all these factors are important and should be included in the SCM framework that is to be developed for the UK construction industry. Four factors did not reach consensus on the degree of importance with a maximum inter-quartile range of 2. These four factors would be reviewed in iterative Delphi rounds (Refer Table 5.7 with inter-quartile ranges for decision in achieving consensus). Table 5.7 is arranged in descending order of the means computed for the importance of each of the CSFs in leading towards integrated SCs.

Table 5.7 - Quartile means for CSFs computed in Round 1a

	CSFs leading to an integrated construction SC	Lower quartile (Q1)	Mean (Q2)	Upper quartile (Q3)	Inter-quartile range (Q1-Q3)	Achieved consensus
1	Positive attitude and approach to working relationships	4	4.3548	5	-1	Yes
2	Support and commitment of leaders/ senior management of all SC member organisations towards integrated SCs	4	4.2258	5	-1	Yes
3	Level of trust between SC members	4	4.1935	5	-1	Yes
4	Extent of communication between SC members	4	3.9677	4.5	-0.5	Yes
5	Degree of collaboration, between SC members, when making key decisions	3	3.8710	5	-2	No
6	Availability of a vision, mission, strategy, policy and procedures for management of SC	3	3.4839	4	-1	Yes
7	Availability and use of IT for collaboration between SC members	3	3.4516	4	-1	Yes

	CSFs leading to an integrated construction SC	Lower quartile (Q1)	Mean (Q2)	Upper quartile (Q3)	Inter-quartile range (Q1-Q3)	Achieved consensus
8	Existence of a protocol for conflict resolution among SC members	3	3.3871	4	-1	Yes
9	Existence of a system to measure performance of SC members (i.e.KPIs)	3	3.3548	4	-1	Yes
10	Promoting engagement of all SC members at the client briefing stage	2.5	3.2903	4	-1.5	No
11	Length of project duration or Continuity of work to sustain the SC	3	3.2903	4	-1	Yes
12	Procurement methods used to procure projects	2	3.1667	4	-2	No
13	Existence of a strategy for training and development of SC members	2	2.9667	4	-2	No

Six respondents to Round 1a (three consultants and three clients) suggested additional factors to the list of 13 CSFs generated based on literature. These once analysed were understood to be incorporated within the existing list of 13 CSFs (refer Appendix 6). The justifications for these categorisations are listed below. Hence the list of CSFs was not further extended.

Support and commitment of leaders/ senior management of all SC member organisations towards integrated SCs

One consultant suggested ‘Dedication of key relevant people to SCs’ as an additional CSF that can be added to the list of 13 CSFs. However, it was understood that this is already encompassed within the CSF ‘Support and commitment of leaders/ senior management of all SC member organisations towards integrated SCs’.

Procurement methods used to procure projects

One client suggested the ‘use of NEC contracts’ to be added to as a new factor. Hence the incorporation of ‘Form of contract’ was considered as an additional CSF. Yet upon further analysis it was realised that the type of NEC contract to be adopted is reliant on time scale and size of project, which makes it closely connected to procurement methods. It was also noted that adoption of NEC contracts will impact on conflict resolution methods as well, which is another CSF for SCM. Hence it was decided that the use of NEC contracts is encompassed at higher levels of integration within these CSFs. Therefore it was not added to the list.

Extent of communication between SC members

One consultant suggested ‘outmoded information’ as an additional CSF. However, it was noticed that outmoded information would be a symptom of the CSF ‘Extent of communication between SC members’ at lower levels of integration. For example, at Level 1, when there is a low level of communication between SC members, it will result in outmoded information.

Another client suggested ‘good personal relationships’ to be added. It was understood that this would be a benefit of good communication and/or good attitude towards working relationships (another identified CSF). Thus it was not added to the list of CSFs.

Existence of a protocol for conflict resolution among SC members

One client suggested ‘subcontracts should mirror the main contract, and allow for adjudication’ be added as another CSF. Yet since adjudication is one approach to conflict resolution it was deemed appropriate to assume that this level of detail should appear within different levels of integration during the Round 2 stage of the survey.

Degree of collaboration, between SC members, when making key decisions

One consultant suggested 'Respect of each party that decisions they make may have an impact on other parties' to be added as another CSF. This aspect is what would lead to SC members, at higher levels of integration, to collaborate when making decisions. Hence it was anticipated that this would be encompassed in higher levels of integration during Round 2, and is not qualified to be added as another CSF.

Availability of a vision, mission, strategy, policy and procedures for management of SC

One consultant suggested 'welcome change' as another CSF to be added. This may or may not be relevant to promotion of SCs. In the case it is applicable; it should appear within the mission of the SC at relevant levels of integration. Hence it was decided not to add it as another CSF.

One client suggested 'Commitment of SC to achieving 'best value for money' as another factor to be added. This is a typical statement that is included within a vision of an organisation. Hence it was realised that similar visions would be described at higher levels within the CSF 'Availability of a vision, mission, strategy, policy and procedures for management of SC'.

Positive attitude and approach to working relationships

One consultant suggested 'Appreciation of SCM benefits' as an additional CSF. This aspect is what would lead to SC members adopting a positive attitude and approach to working relationships, or collaborate when making key decisions. Furthermore training and development of SC members with regard to SCM would promote appreciation of SCM benefits. Thus it seems that this aspect would appear within several CSFs at higher levels of integration; hence not added as an additional factor.

One client suggested 'Good personal relationships' to be added as a CSF. This aspect would be reflected at higher levels of integration where there is a positive attitude and approach to working relationships, as well as, where there is good communication. Since both these are included as CSFs currently, it was not qualified to be included as the fourteenth CSF.

5.5.2 **The Round 1b questionnaire**

Nine out of the 13 CSFs leading to integrated SCs attained consensus, as the inter-quartile range for these 9 factors was l1l or less. Four factors did not achieve consensus. Out of these 4 factors, 3 factors are among the lowest weights. Hence it is important that participants are given an opportunity to maintain or revise their scores in order to find out if these factors should be included in the SCM framework or not.

The questionnaire and cover letter for Round 1b is included in Appendices 7 and 8. The first half of the questionnaire presents the Likert scale of importance for the four CSFs leading to integrated SCs that did not achieve consensus in Round 1a. The respondents are provided with their score in R1a, the overall score of the group and a column to revise their score in this round, if they feel necessary. The latter half of the questionnaire presents the five benefits of integrated SCs that did not achieve consensus, along with the Likert scale of 'degree of expectation'. Each respondent was then provided with their own score for each of these factors in R1a, the overall group score and an opportunity to revise this score if they feel necessary. Not only the participants whose weightings of importance lay outside of 0.25 (Q1) and 0.75 (Q3) quartiles for these 4 factors, but all of the participants of Round1a was contacted for Round 1b and were given an opportunity to maintain or revise their scores to achieve group consensus in light of the average group response calculated from R1a responses.

5.5.3 **Analysis of Round 1b results**

Eleven responded within a week with revised scores for all or some of the factors tested in R1b. The revised scores are presented in the table below. Delphi participants were not pursued beyond one week for the following reasons:

- The factors achieved consensus with the 11 responses.
- Eleven responses is higher than the minimum expected from a Delphi iteration according to Rowe and Wright (1999), Adnan & Morledge (2003) and Linstone and Turoff (1975).

- The respondents should only be provided with an opportunity to revise their scores and should not be persuaded to revise scores.
- Since a holiday period (Easter break) was coming up, extending the survey deadline will not have much of an impact on improving the response rate.
- Fear of annoying respondents at this early stage of survey, where they need to be contacted for further Delphi rounds.
- All participants were given feedback with regard to their scores and group score consequent to R1a. This should lead to more aware and confident respondents in Round 2 of the Delphi survey.

Table 5.8 - Convergence of means for CSFs in Round 1b

		R1a				**R1b**			
	CSFs leading to an integrated construction SC	**Q1**	**Mean**	**Q3**	**Q1-Q3**	**Q1**	**Mean**	**Q3**	**Q1-Q3**
1	Degree of collaboration, between SC members, when making key decisions	3	3.8710	5	-2	3	3.6364	4	-1
2	Procurement methods used to procure projects	2	3.1667	4	-2	3	3.1818	4	-1
3	Promoting engagement of all SC members at the client briefing stage	2.5	3.2903	4	-1.5	2.5	2.8182	3.5	-1
4	Existence of a strategy for training and development of	2	2.9667	4	-2	2	2.8182	3	-1

		R1a				R1b			
	CSFs leading to an integrated construction SC	**Q1**	**Mean**	**Q3**	**Q1-Q3**	**Q1**	**Mean**	**Q3**	**Q1-Q3**
	SC members								

As demonstrated in the table above, the four CSFs have achieved consensus with an inter-quartile range of l1l. These four factors show signs of converging, where the upper quartile mean has shifted downwards, whilst the lower quartile mean has remained the same (except for one factor). Except the factor ‘procurement methods’ all other factors have been rated downwards. Yet, the 0.25 quartile (Q1) for all factors remain 2 (i.e. moderately important) or more, and the mean (Q2) for each factor is nearly 3 or more; hence more than ‘important’ to the success of SCM in construction. Hence all factors will remain in the proposed SCM framework and will be expected to be populated with definitions for each level of integration in Round 2. Cronbach’s Alpha produced for the 13CSFs was more than 0.7, which also indicated that the 13 CSFs can remain in the framework. Further details on reliability measurement using SPSS are discussed later on in this chapter.

Table 5.9 - Finalised means at the end of Round 1b for the 13 CSFs

	CSFs leading to an integrated construction SC	**Lower quartile (Q1)**	**Mean (Q2)**	**Upper quartile (Q3)**	**Inter-quartile range (Q1-Q3)**	**Achieved consensus**
1	Positive attitude and approach to working relationships	4	4.3548	5	-1	Yes
2	Support and commitment of leaders/ senior management of all SC member	4	4.2258	5	-1	Yes

	CSFs leading to an integrated construction SC	Lower quartile (Q1)	Mean (Q2)	Upper quartile (Q3)	Inter-quartile range (Q1-Q3)	Achieved consensus
	organisations towards integrated SCs					
3	Level of trust between SC members	4	4.1935	5	-1	Yes
4	Extent of communication between SC members	4	3.9677	4.5	-0.5	Yes
5	Degree of collaboration, between SC members, when making key decisions	3	3.6364	4	-1	Yes
6	Availability of a vision, mission, strategy, policy and procedures for management of SC	3	3.4839	4	-1	Yes
7	Availability and use of IT for collaboration between SC members	3	3.4516	4	-1	Yes
8	Existence of a protocol for conflict resolution among SC	3	3.3871	4	-1	Yes

	CSFs leading to an integrated construction SC	Lower quartile (Q1)	Mean (Q2)	Upper quartile (Q3)	Inter-quartile range (Q1-Q3)	Achieved consensus
	members					
9	Existence of a system to measure performance of SC members (i.e.KPIs)	3	3.3548	4	-1	Yes
10	Length of project duration or Continuity of work to sustain the SC	3	3.2903	4	-1	Yes
11	Procurement methods used to procure projects	3	3.1818	4	-1	Yes
12	Promoting engagement of all SC members at the client briefing stage	2.5	2.8182	3.5	-1	Yes
13	Existence of a strategy for training and development of SC members	2	2.8182	3	-1	Yes

Table 5.9 lists the 13 factors with the means that they achieved consensus at. They are listed in descending order of importance. The CSFs will be listed in the above descending order in the Round 2 questionnaire. This will mean respondents start populating the framework starting from the most important factor for integration of supply chains. Whilst the most important factor would mean a good starting point for the Delphi experts in Round 2, it will also ensure that the completion rate is higher for these most important factors, in case some respondents do not complete the whole questionnaire. Further the need to provide any examples of how to complete the

questionnaire can be done using the least important factors. This would minimise the researcher's influence in completing the SCM framework, which may lead to subjectivity.

5.5.4 Weightings for critical success factors leading to an integrated construction supply chain

This section deals with computing weightings from the mean scores of the 13 CSFs, which were collected in Round 1 of the Delphi survey. The 9 CSFs that achieved consensus in R1a will hold the means received in R1a for this computation. And the 4 CSFs that achieved consensus in R1b will use the revised scores of the 11 responses that were received in R1b, and for the rest of the 20 respondents the scores received in R1a. The assumption is that the 20 respondents who did not revise their scores in R1b wish to maintain their score submitted in R1a. This assumption allows all CSFs to produce weightings with >30 responses (n=>30). Further analysis in MS Excel is provided in Appendix 10.

Table 5.10 - Weighted averages for CSFs for potential incorporation in a SCM framework

	CSFs leading to an integrated construction SC	**Mean**	**Weighted average**	**Number of responses (n)**
1	Positive attitude and approach to working relationships	4.3548	9.28%	31
2	Support and commitment of leaders/ senior management of all SC member organisations towards integrated SCs	4.2258	9.00%	31
3	Level of trust between SC members	4.1935	8.93%	31
4	Extent of communication between SC members	3.9677	8.45%	31

	CSFs leading to an integrated construction SC	**Mean**	**Weighted average**	**Number of responses (n)**
5	Degree of collaboration, between SC members, when making key decisions	3.7097	7.90%	31
6	Availability of a vision, mission, strategy, policy and procedures for management of SC	3.4839	7.42%	31
7	Availability and use of IT for collaboration between SC members	3.4516	7.35%	31
8	Existence of a protocol for conflict resolution among SC members	3.3871	7.22%	31
9	Existence of a system to measure performance of SC members (i.e.KPIs)	3.3548	7.15%	31
10	Procurement methods used to procure projects	3.300	7.03%	30
11	Length of project duration or Continuity of work to sustain the SC	3.2903	7.01%	31
12	Promoting engagement of all SC members at the client briefing stage	3.2258	6.87%	31
13	Existence of a strategy for training and development of SC members	3.000	6.39%	30
		46.1641	**100.00%**	

The CSF ‘Positive attitude and approach to working relationships’ is the most important factor; hence achieves the highest weighting. All CSFs have achieved weightings in the range 6% - 10%. The weighted averages have been calculated by dividing the mean score for each CSF, by the sum of mean scores of the 13 CSFs. These weightings provide potential to attach scores to the SCM framework, which will enable a single score to be computed when assessing integration of SCs using the developed framework. The weightings included in the framework can act as a guideline for an organisation or a project team when using the developed SCM framework. The 13 CSFs can be used independent of the framework as well to help organisations understand the most crucial issues when managing SCs. This list would be the first of its kind that is made available to the UK construction industry, which has been tested empirically. An index has only been generated in Australia solely for relationship-based construction projects by Yeung et al. (2009).

5.6 *Factor analysis of Delphi Round 1 results*

Prior to including all 13 CSFs leading to integrated SCs in the Round 2 questionnaire, a reliability test and factor analysis was conducted using SPSS software. Cronbach's Alpha is commonly used for testing the consistency in measures or checking the degree of random error of responses (Cronbach, 1951), and for this to be achieved Cronbach's Alpha should be 0.7 or more (Nunnally, 1978). The Cronbach's Alpha generated for the 13 questions was 0.816. Since this value is more than 0.7 the 13 questions can be considered as having being responded free of random error. Hence all 13 constructs can be considered as reliable measures of supply chain integration. It should be noted that Cronbach's Alpha is highest (0.819) when CSF – 'continuity of works' is deleted. All other CSFs produce a lower Cronbach's Alpha, when each item is deleted for testing. Hence these 12 CSFs should be included in the framework, despite some CSFs having means of slightly lower than 3.0.

Factor analysis was conducted using SPSS software to find out if the 13 CSFs could be categorised in to a fewer number of success factors. To attain a more interpretable factor matrix, Varimax rotation with Kaiser Normalisation was used (refer Appendix 10). The 13 items were classified into 5 categories/ factors, where 11 items achieved a loading of more than 0.5 within one factor. The item 'Promoting engagement of all SC members at the client briefing stage' obtained a 0.804 loading for Factor 5, but also obtained a nearly 0.5 loading for Factor 2. And the item 'Positive attitude and approach to working relationships' obtained a nearly 0.5 loading for Factor 2 and a significantly lesser loading for Factor 4. All factor loadings of less than 0.45 have been ignored in this exercise. The 13 items are listed within the factor/ category suggested via factor analysis is listed in Table 5.11. It should be noted however that due to the limited sample size, the variability of these factor loadings is high; thus the generalisability is low. This limitation is quite common in SCM related research as explained in section 4.7.3. The groupings did not indicate any relationship in terms of our theoretical understanding of SCM and its success factors. Hence the 13 items will remain 13 independent CSFs in the SCM framework. This would be consistent with previous research carried out by Yeung et al. (2009) where 10 measures for relationship management was identified in the Australian construction industry.

Table 5.11 - Factor analysis of the 13 CSFs

Items classified into Factor 1	**Factor loadings**
Existence of a system to measure performance of SC members (i.e.KPIs)	0.823
Existence of a strategy for training and development of SC members	0.812
Availability and use of IT for collaboration between SC members	0.640
Existence of a protocol for conflict resolution among SC members	0.591
Items classified into Factor 2	**Factor loadings**
Degree of collaboration, between SC members, when making key decisions	0.870
Availability of a vision, mission, strategy, policy and procedures for management of SC	0.777
Extent of communication between SC members	0.667
Promoting engagement of all SC members at the client briefing stage	0.469
Positive attitude and approach to working relationships	0.453
Items classified into Factor 3	**Factor**

	loadings
Length of project duration or Continuity of work to sustain the SC	0.993
Procurement methods used to procure projects	0.572
Support and commitment of leaders/ senior management of all SC member organisations towards integrated SCs	0.538
Items classified into Factor 4	**Factor loadings**
Level of trust between SC members	0.864
Items classified into Factor 5	**Factor loadings**
Promoting engagement of all SC members at the client briefing stage	0.804

5.7 *Competitive advantages expected from integrated construction supply chains*

5.7.1 Analysis of Round 1a results

All 13 competitive advantages surveyed received 31 responses each (n=31). MS Excel was used to compute the average (Q2), lower quartile (Q1) and upper quartile (Q3) means for the competitive advantages expected from integrated SCs. The difference between Q1 and Q3 provides the inter-quartile range, which indicates if there is consensus in responses for each of the questions answered. Five factors obtained inter quartile ranges more than l1l, thus not achieving consensus. The rest of the eight factors reached consensus, hence was not further tested in R1b.

Table 5.12 - Quartile means computed for competitive advantages from SCM in Round 1b

	Competitive advantages expected from integrated construction SCs	Lower quartile (Q1)	Mean (Q2)	Upper quartile (Q3)	Inter-quartile range (Q1-Q3)
1	Improved predictability of	3.5	4.0968	5	-1.5

	Competitive advantages expected from integrated construction SCs	**Lower quartile (Q1)**	**Mean (Q2)**	**Upper quartile (Q3)**	**Inter-quartile range (Q1-Q3)**
	project budget				
2	Improved ability to deliver projects on time	4	4.0645	5	-1
3	Better value for money to clients	3.5	3.9032	4	-0.5
4	Client satisfaction with regard to responsiveness and assurance of construction professionals	3	3.8710	4	-1
5	Improved quality (and reduced defects) of construction output	3	3.7742	4	-1
6	Improved ability to deliver innovative solutions	3	3.6774	4	-1
7	Improved ability to deliver unique and customized solutions to clients	3	3.5161	4	-1
8	Increased productivity on site	3	3.4839	4	-1
9	Promotion of sustainability	2	3.1613	4	-2
10	Reduced operational costs	3	3.1290	4	-1
11	Reduced accidents at work	2	3.0645	4	-2
12	Increased turnover and profits	2.5	2.9677	4	-1.5
13	Improved employee satisfaction	2	2.9032	3.5	-1.5

The R1a results indicate that improved predictability of project budget and improved ability to deliver projects on time is ‘very much expected’ (a score of 4 or more) from integrated SCs. Whilst Cost and Time criteria have achieved the highest scores, Client Satisfaction and Quality has achieved the 4th and 5th places respectively, with scores of nearly ‘very much expected’. According to Kaplan and Norton’s Balanced Score Card

(BSC) client satisfaction should lead to good financial performance. However, respondents do not seem to recognise 'Increased turnover and profits' as 'very much expected' benefits from integrated SCs yet. This may change over time when the industry starts realising that client satisfaction does lead to client retention, repetitive work, reduced bidding costs, etc. If the industry does not perceive financial benefits originating out of integrated SCs, the collaboration ethos will not sustain for long in the industry. It should be noted however that in Round 1b the item 'Increased turnover and profits' achieve a higher score, and moves up from the 12^{th} place to the 9^{th} place (see tables 5.13 and 5.14 below).

5.7.2 Analysis of Round 1b results

Questions that did not achieve consensus in R1a were retested in R1b. The process and the R1b questionnaire are explained under the section 5.5.2. The R1b questionnaire and the cover letter are available in Appendices 7 and 8. The results for each of the questions retested are listed in Table 5.13 below.

Table 5.13 - Convergence/ Divergence of means of competitive advantages in Round 1b

	R1a				R1b			
Competitive advantages expected from integrated construction SCs	**Q1**	**Mean**	**Q3**	**Q1-Q3**	**Q1**	**Mean**	**Q3**	**Q1-Q3**
Improved predictability of project budget	3.5	4.0968	5	-1.5	4	4.0909	4	0
Promotion of sustainability	2	3.1613	4	-2	3	3.1818	4	-1
Reduced	2	3.0645	4	-2	2.5	2.7273	3.5	-1

	R1a				R1b			
Competitive advantages expected from integrated construction SCs	**Q1**	**Mean**	**Q3**	**Q1-Q3**	**Q1**	**Mean**	**Q3**	**Q1-Q3**
accidents at work								
Increased turnover and profits	2.5	2.9677	4	-1.5	3	3.2727	4	-1
Improved employee satisfaction	2	2.9032	3.5	-1.5	2	3.0000	4	-2

Four out of the five questions retested in Round 1b, converged and achieved consensus. However, one question did not achieve consensus but instead was indicating further divergence. This is the question ‘improved employee satisfaction’ which achieved the lowest mean in Round 1a, implying lower expectancy out of integrated SCs. Even though the item is diverging, the results indicate that divergence is with regard to the upper quartile mean of the item. The lower quartile mean of the item has remained the same in both rounds, which means that respondents do not expect this item to be a benefit achieved from integrated SCs any less than a score of 2, that is ‘moderately expected’. Hence the conclusion is that the item ‘improved employee satisfaction’ is definitely more than moderately expected and on average ‘expected’ from integrated SCs. The inconsistency in responses is in deciding if it is more than ‘expected’, which is not important for this research. Round 1b was concluded at this stage. Additional reasons for concluding Round 1b at this stage are explained in section 5.5.3. It should be noted that competitive advantages or benefits of SCM will not be included in the proposed framework or in the Round 2 questionnaire. The reasons for inclusion of this section in Round 1 are explained in section 5.3.

Table 5.14 - Finalised means for the 13 competitive advantages at the end of Round 1b

	Competitive advantages expected from integrated construction SCs	**Lower quartile (Q1)**	**Mean (Q2)**	**Upper quartile (Q3)**	**Inter-quartile range (Q1-Q3)**
1	Improved predictability of project budget	4	4.0909	4	0
2	Improved ability to deliver projects on time	4	4.0645	5	-1
3	Better value for money to clients	3.5	3.9032	4	-0.5
4	Client satisfaction with regard to responsiveness and assurance of construction professionals	3	3.8710	4	-1
5	Improved quality (and reduced defects) of construction output	3	3.7742	4	-1
6	Improved ability to deliver innovative solutions	3	3.6774	4	-1
7	Improved ability to deliver unique and customized solutions to clients	3	3.5161	4	-1
8	Increased productivity on site	3	3.4839	4	-1
9	Increased turnover and profits	3	3.2727	4	-1
10	Promotion of sustainability	3	3.1818	4	-1
11	Reduced operational costs	3	3.1290	4	-1
12	Improved employee satisfaction	2	3.0000	4	-2
13	Reduced accidents at work	2.5	2.7273	3.5	-1

The scores for each of the 13 benefits at the end of R1b are listed in the table above. The benefits are listed in descending order of expectancy from integrated SCs. It can be observed that up to the 8th benefit, starting from the most expected, the list has not changed from R1a to R1b. The most expected benefits are with regard to cost and time factors. The 4th and 5th benefits expected are client satisfaction and quality respectively. The next two expected benefits deal with the SC's ability to provide innovative solutions and customised solutions. The close collaboration of SC members, when working within an integrated SC, will no doubt lead to innovative and customised solutions, as claimed in previous literature within non-construction industries. The benefits that achieved a score between 3.0-3.5 are increased productivity, turnover and profits, sustainability, employee satisfaction and reduced operational costs. In conclusion construction professionals do expect most benefits achieved via SCM in non-construction industries within the construction industry.

5.8 *The Delphi Round 2 survey*

5.8.1 Construction of Round 2a questionnaire

In order to produce a SCM framework, the x axis and the y axis, or in other words the column headings and the row headings of the framework need to be decided. The y axis or the row headings of the framework would be the 13 CSFs leading to an integrated SC. These factors were assembled using previous literature discussed in chapter 3 and then were tested for relevance and importance, among construction professionals, to a SCM framework in Round 1 as explained previously. The x axis or the column headings would be the levels of integration, according to the non-construction specific SCM models, available in previous literature.

Table 5.15 - Levels of integration of non-construction specific SCM models

Citation	**Industry**	**Levels of integration**	**No. of levels**
Stevens (1989)	Generic	3 levels of intra-firm integration and fourth stage of inter-firm	4

Citation	Industry	Levels of integration	No. of levels
		integration	
Supply chain maturity model (PRTM, 2002)	Generic	Functional focus, Internal integration, External integration and Cross-enterprise collaboration.	4
The SCM maturity model (Lockamy and McCormack, 2004)	Generic	Ad hoc, Defined, Linked, Integrated and Extended.	5
Hoffman and Reiner (2006)	Manufacturing	Disconnected processes, Internal integration, Intra-company integration and limited external integration and Multi-enterprise integration.	4
McLaren (2006)	Web-enabled manufacturing	Functional Focus, Internal Integration, Linked Network, Integrated Network and Optimised Network	5
Proposed SC maturity model (Vaidyanathan and Howell, 2007)	US construction industry	Ad-hoc, Defined, Managed and Controlled	4

It should be noted that models that were not descriptive with regard to different levels of integration were not included in Table 5.15, as the aim of the research is to develop a framework with levels of integration, which allows assessment and improvement of SCs. Table 5.15 is a summary of the SCM models, which demonstrated stages of integration, from chapter 3 of this thesis. Some of these models have been proposed as generic models whilst some have been developed with specific industries in mind, and some of these models have been developed by researchers whilst some by practitioners or service organisations. In either case what is noticeable is that most of these models have been classified with four levels of integration, and few of the models with five levels of integration. Thus it was put forward to the pilot experts of this survey, with examples from the literature review. It was unanimously decided that the levels of integration should be four. Therefore it was decided that the levels of integration sought for this SCM framework would be 4 for the following reasons:

- Most SCM models presented in previous literature consists of 4 levels of integration.
- The pilot experts were favourable of 4 levels of integration.
- A 5^{th} level of integration would be more appropriate for the e-business world, where the 5^{th} level can be visualised as an entire SC collaborating as a virtual organisation. Whilst it is possible that a construction project organisation becomes a virtual organisation in the distant future, it would be difficult for construction professionals to engage in the Delphi survey at the present time if a 5^{th} level is included.
- The Delphi respondents would find it easier to populate 4 levels of integration, than 5 levels of integration. A 5^{th} level can be added to the framework, if required, in the future once the framework of 4 levels is populated and tested for validity.

The four levels of integration were given a short definition or an explanation, based on some of the models discussed in chapter 3. This was provided as guidance for respondents, and was explained that they can suggest any other definitions for the levels of integration in this round (R2a). The four levels of integration were defined as follows:

Level A- Minimal integration: Departments/Sections within the assessed construction organisation are not integrated/ collaborative. This should be considered the worst case scenario that has been observed within the construction industry.

Level B- Internal integration: Departments/Sections within the assessed construction organisation are internally integrated, but not integrated with any external organisations.

Level C- Some external collaboration: In addition to internal organisational integration, there is some collaboration with few external organisations.

Level D- Extensive external collaboration: There is evidence of extensive internal and external organisational collaboration. This would be the best case scenario that can practically be expected from construction supply chains.

All respondents were contacted via telephone again for Round 2a to explain the ‘skeleton’ of the framework. They were explained that the framework may be filled hypothetically, especially at Level D, since respondents may not have had real-life experience of all the levels of integration of all 13 CSFs. After all, according to Manoliadis et al. (2006) Delphi has been a technique that has been developed to forecast issues using expert opinions.

The Delphi participants were requested to respond to Round 2 with a single organisation in mind, ideally the organisation they are currently employed at, and the relationships this organisation has within the organisation and with other organisations. They may consider a single project that the organisation deals with or multiple projects that their organisation deals with typically. The projects may be past or ongoing. The researcher decided that the SCM framework, once developed, would be beneficial to the industry’s use from an organisational point of view as it is an organisation that can make improvements in the long run. However, the construction industry being a project-oriented industry, the project perspective is also embedded into the framework as participants respond based on a typical project(s) from their organisation. The organisational and project perspective would make this framework unique, as O’Brien et al. (2002) claims that most construction SCM research is project oriented. This makes it difficult for construction organisations to understand and apply any results within a long-term organisational context. Hence the developed framework would be useful in filling this knowledge gap.

5.8.2 The pilot survey and revision of the Round 2a questionnaire

The questionnaire at this stage was arranged in two parts: Section A expected participants to suggest an example of best practice or the ultimate goal for each of the 13 CSFs, and Section B expected the participants to show progression of each of the

13 CSFs along 4-5 levels of integration, where the best practices identified in Section A would be presented at the highest level of integration. The pilot experts were questioned with regard to the clarity, time taken to respond, ease of responding, etc. The common reaction was that Section A was not necessary, but that they could respond to Section B straightaway, which would also save time taken to complete questionnaire. It was unanimously agreed that 4 levels of integration would be appropriate for the construction industry. Some participants also suggested including some examples of progression of CSFs which would clarify the style of answering. The questionnaire emailed to pilot experts in preparation for Round 2 is included in Appendix 11.

The questionnaire was revised based on the pilot survey. Section A was removed and Section B was modified to 4 levels of integration, although the participants were told that they can change the number of levels, if they so wish. The cover letter was revised to include examples of best practices for the 2 CSFs that were found to be least important in Round 1. This is in expectation of minimising the researcher's influence on the Delphi participants' responses to Round 2. The revised cover letter and questionnaire are included in appendices 12 and 13.

Delphi Round 2a was designed bearing the finalised Likert scores received at the end of Round 1b. All factors were organised in the order of importance, starting with the most important factor. The least 2 important factors based on average Likert scores established in Round 1 were populated with suggested answers as requested by the pilot experts. These suggested answers were based on literature, responses of the pilot survey, knowledge of the researcher, and then was validated by the manager of Constructing Excellence in Northern Ireland and the supervisors of this research project. It is expected that the outcome, that is the SCM framework is influenced in the least, as these 2 factors are only moderately important according to the Round 1 surveys. It was also assumed that in the case where participants were overwhelmed by the Round 2 questionnaire which may lead to incomplete answers, the most important CSFs would have a higher chance of being completed due to being at the top of the list.

5.8.3 Number of respondents

The Round 2a questionnaire was sent to the 31 respondents of Round 1a. In a Delphi survey it would be the usual practice to select the respondents of the previous iteration for the next round. This practice ensures that the invited participants of Round 2a are genuine experts of construction SCM, as they were able to complete the Round 1a questionnaire which tested them on their knowledge and experience of SCM in the construction industry via a series of open ended and closed ended questions. Hence these are 31 'naturally selected' experts, as they have already demonstrated that they have the ability to understand construction SCM. These respondents have an increased ability to understand the Round 2a questionnaire (which should increase the response rate to Round 2a), as they have already participated in Round 1a, Round 1b (if relevant) and received feedback on Round 1a results.

Fifteen responses were received within a period of 3 months, which accounts to a 48% response rate. The survey took very long primarily due to two reasons. Firstly, the survey took place during the 3 summer months, where most participants were on leave for some amount of time, which led to work accumulating that they needed to address prior to responding this questionnaire. Secondly, this is a relatively complex and time consuming process where each participant is expected to complete 52 open ended questions, i.e 13 CSFs across 4 levels of integration. In fact, some of the participants who responded to this round mentioned that they completed this questionnaire in collaboration with another expert from within their organisation, due to the complexity of the answers they had to generate.

Figure 5.3 shows the number of responses received for each category, out of the total of 15 responses. However, one response each from the client and supplier categories were not useful. For example, the respondent has only completed a single level for all 13 CSFs, which makes it difficult for the researcher to analyse the suggested progression of each CSF across the 4 levels. Hence such responses, which make it difficult to understand inferences, were discarded. This reduced the number of usable responses for analysis to 13. This is higher than the minimum expected from a Delphi round according to Rowe and Wright (1999), Adnan & Morledge (2003) and Linstone and Turoff (1975).

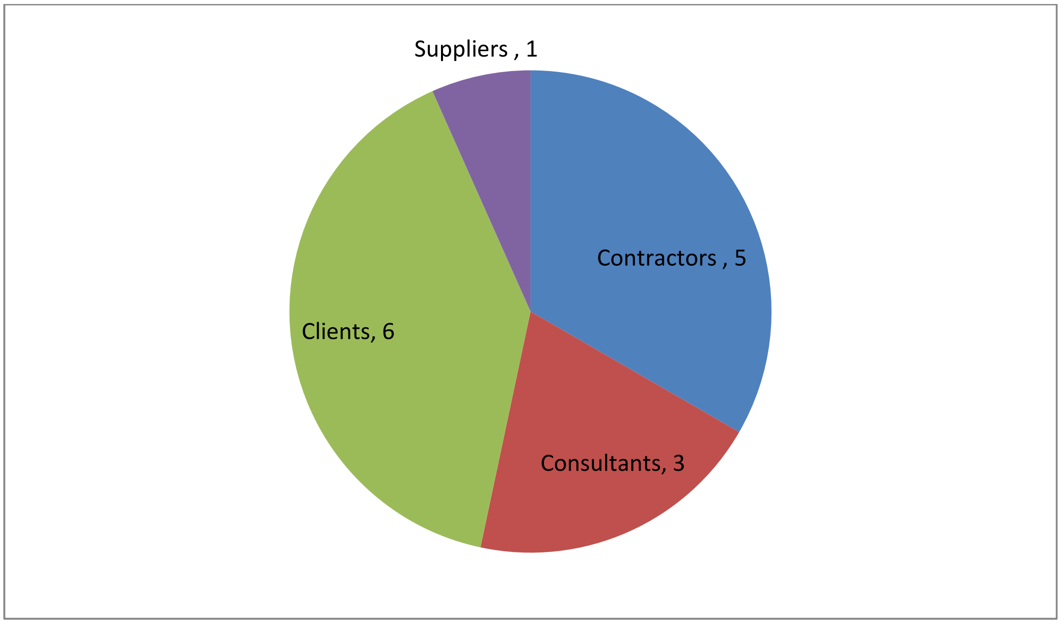

Figure 5.3 - Composition of respondents to Round 2a

Subcontractors and suppliers, that is tier 4 organisations of a construction supply chain, had a lower response rate than other categories in Round 2a (Refer Table 5.16). Their response rate has been significantly lower in this round. In fact, the single response received was incomplete, hence not usable. This probably is due to the lack of expertise at tier 4 to engage in such a complex process of populating an SCM framework. It can be noted that their assessment of their level of expertise, as mentioned in R1a, is 3.17 on average. This is the lowest average score among the categories across the four tiers.

Hsu and Sandford (2007) explain that the assumption that all Delphi experts are equivalent in knowledge and experience is questionable. However this is an assumption that is made with regard to Delphi participants (Altschuld and Thomas, 1991). Hsu and Sandford (2007) explain that their expertise could be different, where some are knowledgeable on in-depth issues, whilst others are knowledgeable on a number of different issues. This phenomenon is particularly true in this research, as different tiers of the SC will demonstrate different types of expertise. Thus despite the selection of ‘experts’ for a survey, some experts may not be able to respond to certain questions as has happened with regard to Tier 4 respondents in this survey. This is a limitation of this research.

The aim of this round was to collect expertise from all types of SC members in order to include in the framework. Yet due to lack of usable responses from tier 4, the framework now only represents views of clients, consultants and main contractors; the main three tiers of a SC. However, it should be noted that Tier 4 respondents claimed the 13 CSFs included in the framework as important to SCs in the first two rounds of the Delphi survey. Therefore the developed framework should be of some relevance to Tier 4 as well. Confirmation or rejection of this hypothesis can be tested at the end of the e-survey (refer Chapter 6).

Table 5.16 - Response rates for Round 2a and the expertise of respondents

	Average score of level of expertise	**Response rate based on total number of responses received**	**Response rate based on number of *usable* responses received**
Contractors (Tier 3)	4.00	63%	63%
Consultants (Tier 2)	3.33	33%	33%
Clients (Tier 1)	3.25	75%	63%
Suppliers (Tier 4)	3.17	17%	Nil

The average score of expertise per category and their response rates to Round2a are listed above in Table 5.16. The response rates are presented as the total number of responses received and the total number of usable responses received. This is due to a single response from each of the categories Client and Supplier not being usable for the analysis of this research. The table is arranged in descending order of average score for level of expertise.

As in previous rounds clients have generated a high response rate, perhaps due to high interest in SCM and/or obligation to respond to emails due to belonging to a public-sector organisation. The contractors and consultants, the 2 categories with highest level of expertise did not submit any incomplete responses, suggesting that they were able to complete this exercise more accurately. This result indicates again that the measurement of expertise of SCM based on one's own opinion is realistic. However, with such low absolute number of responses it is difficult to devise more firm deductions.

5.8.4 The analysis of Round 2a data

To develop the SCM framework the responses were processed in four steps. This process, which is called analytic induction, is further discussed by authors such as Farrell (2012), Fellows and Liu (2008) and Vaus (2001). Firstly, 52 separate documents were created for each level of integration of each CSF. As there are 13 CSFs and 4 levels of integration named Level A, B, C and D, the 52 documents were titled 1A, 1B, 1C, … 13C, 13D. Then each of these 52 documents was filled in with the 13 responses received for each level of integration of the CSFs. This stage was referred to as the Transcription stage, as this involved compiling the responses received in preparation for analysis. The documentation of this process is included in Appendix 14.

The second process was referred to as the Extracting stage, where each of the 13 responses per document created was analysed and summarised based on common themes for that document. This is the lengthiest stage of this process, as a relatively diverse set of responses have to be summarised into a few common themes. The third stage, called the Abstracting stage was to compile these extracts into a final set of statements, where similar extracts would be merged to form one statement. Lastly, the statements created at the Abstracting stage are put together to form a paragraph(s) for inclusion in the SCM framework. The amount of data deleted or summarised reduced as the stages progressed, with minimal changes in the final stage. The transcripts, extracts, abstracts and the final SCM framework are included in Appendices 14-16 respectively.

5.8.5 The Round 2b survey

The respondents to Delphi Round 2a were emailed the SCM framework, and were asked to verify if this is a fair representation of their responses. They were also asked to give any further comments with regard to the usability of the framework. The R2b questionnaire is included in Appendix 17. Ten responses were received within a month for this survey, and the survey was deemed concluded at this point. Ten responses is sufficient for a Delphi iteration according to Rowe and Wright (1999), Adnan & Morledge (2003), Okoli and Pawlowski (2004) and Linstone and Turoff (1975). All 10 responses confirmed that the SCM framework has encompassed their responses accurately, and were positive about the usability of the framework. The transcripts, extracts, abstracts and SCM framework were also presented to the research supervisors and a senior independent professional of the construction industry for added validity of the process of producing the framework.

Hence this is the end of a Delphi survey, which consisted of 4 rounds; R1a, R1b, R2a and R2b. The survey and relevant analysis was conducted over 11 months during 2010 and 2011, and the attrition of respondents over the 4 rounds is shown in Table 5.17 below:

Table 5.17 - Attrition of respondents over the four Delphi rounds

Database of contacts	Responded to R1a	Responded to R1b	Contacted for R2a	Responded to R2a	Responded to R2b
67	31	11	31	15	10

	Database of contacts	**Responded to R1a**	**Responded to R1b**	**Contacted for R2a**	**Responded to R2a**	**Responded to R2b**
Response rate		46%	35%		48%	67%

5.9 *The proposed SCM framework*

The SCM framework developed, via the Delphi method, to assess and improve integration of construction SCs is presented in Table 5.18. The framework is also included in Appendix 16 to maintain the flow of the appendices, which demonstrates the sequential development process adopted in this research. This framework is a significant contribution to knowledge, as it presents a method for construction organisations to assess and improve their SCs. The 4 levels of integration included in the framework makes it easy for professionals to use it, and is the only model that consists of such stages available to the construction industry (refer chapter 3).

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
1	**Positive attitude and approach to working relationships**	Minimal understanding of the need for collaboration. There is not much interaction between SC members and no facilitation of working relationships. SC members are more 'contract focused' than 'partner oriented'. Will probably have separate site locations for project participants and no agreement of project objectives.	Appreciates the need for collaboration. Some collaboration apparent, especially at senior managerial level and/or within a firm. Project meetings and objectives may be set excluding external organisations. May still have separate site locations for project participants from different firms.	Collaborative relationships have developed with key SC members. If not, will be starting to build relationships with selected SC members, at least after tender stage. Some may be uncertain about how to engage in a collaborative relationship. However, the firm would demonstrate to external organisations that they appreciate collaborative working. Will probably lack of a strategic approach to collaboration. Key SC members might share same site offices.	The SC is now established, and there are signs of interdependability among SC members. Collaboration is encouraged in every aspect of business. SC members are involved throughout the project. Objectives for collaboration may be set, and corporate goals may be aligned to achieve these objectives. Conditions of Contract and MoUs support partnering/ collaborative working. Key SC members may share site offices.

		Level 1 (Minimal Integration)	**Level 2 (Internal Integration)**	**Level 3 (Some external collaboration)**	**Level 4 (Extensive external collaboration)**
2	**Support and commitment of leaders/ senior management of all supply chain member organisations towards integrated supply chains (SCs)**	There is almost no support by senior management to collaborate. They display selfish behaviour and possibly are not aware of benefits of collaboration.	There is limited support by key personnel to collaborate. Promotion of collaboration will be limited to internal departments/ sections.	Senior management support collaboration. They are now committed to extending collaborative practices to a few selected external organisations. Training may be provided to promote trust and communication with external organisations.	Senior management support collaboration, of all SC members. This support may be for the long-term or for the duration of project. There will be documentation and procedures to support collaboration and/ or collaboration may be embedded in culture at this stage.
3	**Level of trust between supply chain members**	Nil to limited trust present among people. Lack of trust may be due to poor relationships, communication and/or understanding of SCM. Such companies will practice	There is limited trust. Trust might be one-way. Trust may be within a single organisation. There will be ineffective external relationships and strict procedures when	Some trust between selected SC members. There will be good working relationships with these SC members.	A high level of trust exists among all SC members at this stage. Trust exists among all SC members. Trust is built-up through long term partnering, frequent communication,

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
		closed book accounting, operate within silos, observe blame culture and there is hostility and competition between SC members.	communicating externally. Lack of trust may be due to poor understanding of SCM. Such companies will practice closed book accounting.		regular meetings and team building events. Trust is apparent due to open discussions, honest advice, open book accounting, good working relationships from early stages of a project and prompt payments to all SC members.
4	**Extent of communication between supply chain members**	There is no or little communication. Any communications will be limited within departments and to contractual requirements. Communication will be via telephone and not through formal methods.	There is formal and informal communication at this stage. Communication within an organisation will be good, although there will still be minimal communication with SC members.	There is good communication with selected SC members. Communication will be regular and will take place both formally and informally.	There is good communication with all SC members from an early stage of project. Communication at this stage is frequent, efficient, effective, constructive and extensive. The formal communication system will be accessible by all

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
					SC members.
5	**Degree of collaboration, between supply chain members, when making key decisions**	There is minimal collaboration. Any collaboration will be limited to contractual requirements.	There is good collaboration internally within a single organisation. However, there is limited collaboration with external organisations. No active collaboration between SC members.	There is good collaboration among selected SC members. Structured meetings may be organised regularly.	There is good and proactive collaboration with SC members. Collaboration with all SC members is supported via communication systems and regular meetings.
6	**Availability of a vision, mission, strategy, policy and procedures for management of supply chain**	A vision, mission, strategy, policy or procedures for management of SC does not exist.	Some documentation on vision, etc. exists but is not communicated to SC members. Therefore vision etc. will not be aligned with the rest of the SC members.	There is a formal policy on vision, etc. and they may include references to key SC members. This might be communicated to SC informally, but may not be fully explained, understood or followed.	There will be formal and detailed documentation in place, encompassing the entire SC. The entire SC will contribute to and support the vision, mission, etc.

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
7	**Availability and use of IT for collaboration between supply chain members**	No or inadequate IT systems in place. Usage of IT will be limited to emails/fax. SC members have limited IT skills	Internal IT systems are established at this stage. However the software will be incompatible with external SC members. Hence there will be limited access for and insignificant use of IT between SC members.	There will be established IT systems internally with limited access for some SC members. The IT systems will be internet-based, promoting accessibility. However IT compatibility with SC members could be ad hoc. SC members, at this stage, will have good IT skills.	There will be extensive IT collaboration, where IT training is provided and access allowed for all SC members. The IT strategy will be agreed across the SC and IT usage for collaboration will be made compulsory. All SC members will have good IT skills and compatible IT systems.
8	**Existence of a protocol for conflict resolution among supply chain members**	No protocol in place for conflict resolution among SC members; conflict resolution is limited to contract mechanisms.	Some protocols in place for conflict resolution but not formally communicated to SC members. There may be different interpretations of protocols.	Protocols in place among key SC members and is formally communicated along the SC. There still may be different interpretations of protocols. SC members are encouraged to use conflict resolution and external	There is a formal protocol for entire SC and all SC members get involved in developing the protocol. Regular meetings are held to address issues and avoid conflict.

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
				advisors may be appointed, if necessary.	
9	**Existence of a system to measure performance of supply chain members (i.e.KPIs)**	There is no system in place for performance measurement.	There is some use of performance measurement. At this stage performance measurement may focus only on a single organisation.	There is limited collaborative performance measurement. Performance measurement systems are inconsistent across the SC and some SC members may be unsure of how to measure performance.	There are systems in place for collaborative performance measurement. These systems are comprehensive, consistent, aligned across the SC, contractual and formal. SC members are involved in the development of this system, understand the process of measurement and are proactively encouraged to use performance measurement.
10	**Procurement methods used to**	Traditional procurement methods are used, and is driven through price alone.	Procurement is mostly price driven and SCM (although may be mentioned) is not	Procurement methods are price and quality driven, and there is commitment to key SC	Procurement methods promote partnering, long-term collaboration, PRP and open-

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
	procure projects	Procurement methods are chosen in an ad hoc manner and SCM is not mentioned or encouraged.	encouraged. SC members will be open to new procurement methods. Selection of procurement methods would be for individual gain rather than of project. The focal organisation could be committed to creating long-term partnerships and a regular group of SC members invited to tender.	members for long-term partnerships. Repeat projects are common with established SC members. The focal organisation may create a SC strategy and inform SC members, and the procurement methods may detail the use of an integrated SC and actively encourage their use.	book accounting. The SC demonstrates good understanding of all types of procurement methods. The procurement strategy is developed by all SC members to suit project, and there is commitment to key SC members for long-term partnerships.
11	**Length of project duration or Continuity of work to sustain the supply chain**	No commitment to SC for continuity of work.	There might still be no commitment to external organisations for continuity of work. However, if several projects are carried out, collaboration might be	At this stage there will be some successful collaboration with long-term projects and repeat projects. There will be informal commitment to key SC members regarding	There is a formal contractual commitment to continuity of work and long-term relationships with SC members. SC members are well-integrated even for a

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
			considered and future projects indicated to SC members.	possible continuity of work. Indication of further work will be based on good performance.	single or short-term project and are actively encouraged to bring opportunities/projects to collaborate in future.
12	**Promoting engagement of all supply chain members at the client briefing stage**	There is minimal involvement of SC at the client briefing stage. At best, there might be some informal briefing.	SC members will be aware of client briefing stage, but have no access to documentation. There will be informal briefing with key SC members.	SC members are provided with client brief. They will not input to the development of the brief although their opinions may be sought and they are somewhat involved at this stage.	All SC members are involved in developing the client brief.
13	**Existence of a strategy for training and development of supply chain members**	There is no strategy for training and development and minimal training provided to the SC and internally.	A strategy for training and development of SC members exists. However, training and development is focused within a single organisation.	A strategy for training and development of SC members exists and adherence to the strategy is encouraged. Sporadic training may be offered to some SC members.	A strategy for training and development of SC members exists and adherence to strategy is made compulsory. There will be regular and accountable training provided to all SC members. These

		Level 1 **(Minimal Integration)**	**Level 2** **(Internal Integration)**	**Level 3** **(Some external collaboration)**	**Level 4** **(Extensive external collaboration)**
					programmes are designed and implemented with the involvement of the SC.

Table 5.18 - The proposed SCM framework

5.10 *Summary*

The Delphi method allowed this research to create a significant contribution to knowledge – a framework for construction supply chains to assess and understand improvements. The initial Delphi rounds also allowed CSFs to be weighted and prioritised based on Likert scores, understand the perception of construction professionals with regard to benefits derived from integrated SCs and develop insight about the level of expertise on SCM of construction professionals belonging to different sectors of the construction industry. The most prioritised CSFs by the construction experts were positive attitude and approach to working relationships, commitment of leaders to SCM, level of trust between SC members and extent of communication between SC members. The most expected benefits from SCM were improved predictability of project budget, improved ability to deliver projects on time and better value for money to clients. It was also revealed that professionals from large construction organisations hold the highest level of expertise, based on their own opinion and the ability to respond to questionnaires requiring complex answers. The supplier end of the SC claimed the lowest level of expertise in SCM. There was also indication that small construction organisations understand the concept of SCM less, and perceive them as not being involved in the management of SCs. The developed framework is available in Table 5.18. The testing of the framework and use of the framework to assess the current and future level of integration in the UK construction industry are discussed in the next chapter, chapter 6.

Chapter Six

Evaluation of the framework

Chapter 6 – Theory testing: Operationalising the framework

6.1 Scope of chapter

This chapter discusses the data collection and analysis of the e-survey, which was aimed at testing the proposed SCM framework for its ease of use, applicability, etc. The development of the SCM framework, via the Delphi method, was discussed in the previous chapter (chapter 5). The e-survey allowed construction professionals in the UK to assess their SCs using the proposed SCM framework and to provide feedback on the framework, as part of theory testing. The need of this process for theory building and theory testing was discussed in chapter 4. The chapter begins with an introduction to the questionnaire, categories of respondents and response rates. It then moves on to explaining the results for each of the three sections of the questionnaire. The latter part of the chapter discusses the feedback received for the proposed SCM framework and the conclusions of the propositions to test the SCM framework.

6.2 The propositions to be tested in the e-survey

Theory testing approach begins with a theory, such as the SCM framework created using previous literature and a Delphi survey; and consequently uses deductive reasoning to check if the propositions of the theory comply with the observations at an empirical level, such as via a questionnaire survey as Vaus (2001) advocates. The propositions appropriate to test the theory proposed in this research, which is an SCM framework that allows assessment and improvement to construction supply chains, are listed below:

Proposition 1: Construction professionals find it easy to use the framework.

Proposition 2: The number of levels of integration in the framework is suitable for the construction industry.

Proposition 3: Construction professionals find the framework useful in gauging the level of SC integration in a project.

Proposition 4: The framework indicates how to improve and move on to the next stage of SC integration.

Proposition 5: All sub-sectors of the construction industry can relate to the SCM framework in general.

6.3 The development of the questionnaire

In order to conclude the propositions of the questionnaire survey, the questionnaire was structured in three sections as follows. The questionnaire would then allow 'operationalising' of the SCM framework among construction professionals and receive feedback on the framework.

Section A: General information

Section B: Assessing the construction organisation's supply chains

Section C: Feedback on the framework

The questionnaire was pilot tested for length, time taken to respond, clarity of questions, ease of navigation and presentation. The three pilot respondents commented negatively on the length of the questionnaire, which initially had each of the descriptions of the 13 CSFs in the SCM framework included as part of Section B. The pilot survey led to the framework being presented as a separate document along with the questionnaire. The questionnaire then included a short tick box exercise in section B where the respondents tick the box appropriate to their level of integration, based on the SCM framework that they have been provided. This questionnaire is included in Appendix 18. Section B of the questionnaire where respondents assess their current and future levels of integration is necessary as part of the theory testing process explained by Gill and Johnson (2010; refer Figure 4.6). The 'operationalising' of the framework allow respondents to provide feedback on the developed framework based on actual experience of using the framework for which it is intended for. Since the aim of the framework is to help organisations assess and improve their SCs it becomes important for respondents to identify their future level of integration as well. The description of the identified future level of integration would then indicate the user what to improve to move onto the next stage. The respondents can then provide feedback with regard to the framework's use with regard to helping them understand how to improve their SCs.

Section A of the questionnaire asked about the respondents' level of involvement with construction SCs, their level of expertise in SCM (in their opinion), the type of organisation they work for, where their office is based and the size of their organisation based on EU guidelines. These questions will allow patterns or correlations to be observed, particularly with propositions intended to be tested in this survey. Section C of the questionnaire presents questions which assist in concluding the propositions of the survey.

6.4 The execution of the questionnaire survey

6.4.1 Categories of respondents

The main purpose of this survey was to test the developed framework with regard to its applicability to the construction industry. The end-user was expected to be a professional who deals with SC members from the categories client, consultant, contractor, subcontractor and material or plant supplier. The categories selected were the same as used in the Delphi survey, as can be seen from Table 6.1.

Table 6.1 - Categories of respondents

Classification	Category	Sub-categories
Tier 1: Demand side	Clients	Public & Private sector clients
Tier 2: Design side	Consultants	Project managers, Quantity Surveyors, Engineers & Architects
Tier 3: Implementation side	Main contractors	Main contractors; subdivided as large firms & SMEs.
Tier 4: Supply side	Suppliers	Trade and specialist subcontractors & Material and plant suppliers.

6.4.2 The response rate

The survey was conducted over the three summer months in the UK, among 360 construction professionals. The rationale for the selection of the construction professionals was explained in chapter 4. A lengthy period of time such as 3 months was required due to many of the respondents being on holiday. Moreover it took 2 months for all companies potentially available to respond to the survey, to be contacted. Yet after 3 months of the survey, the response rate was 19% which is quite low. This could be due to several reasons.

- Involvement in integration of SCs is still quite low in the UK. Thus a recipient who deems his/her self as not involved in integrated SCs will not participate in the survey.
- A recipient who is not enthusiastic about SCM in construction will not be inclined to participate in the survey. It should be noted that enthusiasm for SCM has somewhat declined with the prevailing economic downturn, despite government reports and initiatives.
- A recipient who has just returned from holiday will have to 'catch up' on work before they have spare time to respond to the survey.
- Emails sent to general inquiry email boxes in certain companies may not have been forwarded to the correct professional.

Further it was observed that although quantitative research has been conducted for SCs in the manufacturing industries (Kotzab et al., 2005), there is no similar research available for construction SCs worldwide (Ebrahimy et al., 2011). This is probably due to the reason that many construction firms are not yet involved in SCM, as in the manufacturing industries. Hence an absolute number of 68 responses is a significant number of responses for a SCM research in construction. Moreover Groves (2002) has established that there is no response rate below which it can be identified as leading to non-response bias. Similarly that there is no response rate above which might indicate non-response bias. Hence there is no necessity to continue the survey in order to improve the response rate of 19%, especially after several reminders. This response rate is in line with other SCM research conducted in the construction industry (refer 4.8.3). Further Gill and Johnson (2010) argue that it is better to analyse the non-respondents with those who respond, rather than incurring extra costs on an increased sample size which may not be representative of the population due to the differences in population of respondents and non-respondents/ late respondents.

6.4.3 Non-response bias

Curtin et al. (2000) and Scott et al. (2000) found that significant response bias could be present in situations where there have been high or low response rates. Hence as Gill and Johnson (2010) advocates an analysis of the early and late respondents was carried out, to observe any differences between them and gain insight into respondents and non-respondents.

Late respondents found the framework slightly difficult to use, when compared to the early respondents (Table 6.6). They also found the framework more useful in assessing SCs and more helpful in prescribing improvements when compared to the early respondents (Table 6.4 and 6.5). However, they have claimed more expertise and involvement in SCs than early respondents (Table 6.2 and 6.3). It is not clear how an ‘expert’ could find the framework comparatively difficult to use, and more helpful towards assessment and improvement. Possibly they are overestimating their level of expertise and involvement in SCs.

Table 6.2 - Analysis of response bias for the question ‘involvement in SCs’

	Number	Mean 1 = ‘Highly involved’; 4 = ‘Not much involved	Std. deviation
Early respondents	20	2.35	1.040
Late respondents	20	1.95	.945

Table 6.3 - Analysis of response bias for the question 'expertise in SCM'

	Number	Mean 1 = ‘Poor’; 5 = ‘Excellent’	Std. deviation
Early respondents	20	3.00	.973
Late respondents	20	3.20	1.152

Table 6.4 - Analysis of response bias for the question 'usefulness of SCM framework to assess current level of integration of SCs'

	Number	Mean 1 = 'Very useful' 3 = 'Not at all useful'	Std. deviation
Early respondents	20	1.85	.587
Late respondents	20	1.80	.523

Table 6.5 - Analysis of response bias for the question 'helpfulness of SCM framework in understanding how to improve SCs'

	Number	Mean 1 = 'Very helpful' 4, 5 = Framework not at all helpful	Std. deviation
Early respondents	20	2.05	.945
Late respondents	20	2.00	.858

Table 6.6 - Analysis of response bias for the question 'ease of use of SCM framework'

	Number	Mean 1 = 'Extremely easy to use' 5 = 'Extremely difficult to use'	Std. deviation
Early respondents	20	2.05	.759
Late respondents	20	2.25	.639

6.5 Analysis of Section A – General information

6.5.1 Country of respondent's organisations

Out of the 68 respondents, 65% were based in NI, 23% were based in GB or the whole of UK, 9% from the ROI whilst 3% have skipped the question (refer Figure 6.1). Since the scope of this research was set as the UK, the six responses received from the ROI and the 2 responses without an identified country were eliminated for the rest of the analysis. The higher percentage of responses from NI would be because University of Ulster, where the researcher is based, is located in NI. However, no adjustments were made when analysing data to compensate for any lack of balance in responses from NI and rest of the UK, as correlation analysis, using SPSS v20, demonstrated that there was no significant difference between responses from NI and rest of the UK (refer table 6.7). According to Cohen and Holliday (1996; cited in Farrell, 2011) a correlation figure of less than 0.2 refers to little or no relationship. Each of the questions identified in Table 6.7 was tested for correlation with geographical area which generated correlation figures of less than 0.2, indicating little or no relationship.

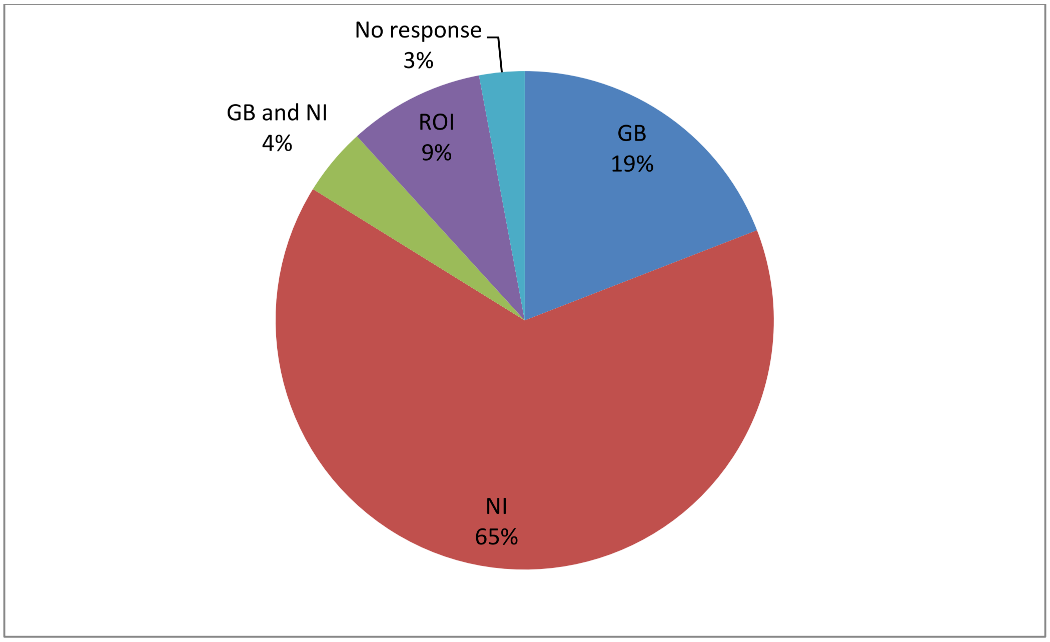

Figure 6.1 - Country of organisation of all 68 respondents

Table 6.7 - Correlation analysis of respondents' answers based on geographical location of organisation

Questions from Section A and C of the questionnaire	**Pearson Correlation**	**Sig. (2-tailed)**	**N**
Involvement in SCs	-.119	.336	68
Expertise in SCM	-.024	.844	68
Turnover of organisation	-.137	.273	66
Number of employees	-.125	.318	66
Type of organisation	.034	.783	68
Ease of use of SCM framework	.067	.588	68
Understanding indications to improve from SCM framework	-.024	.849	68
Number of levels for SCM framework	-.150	.225	67

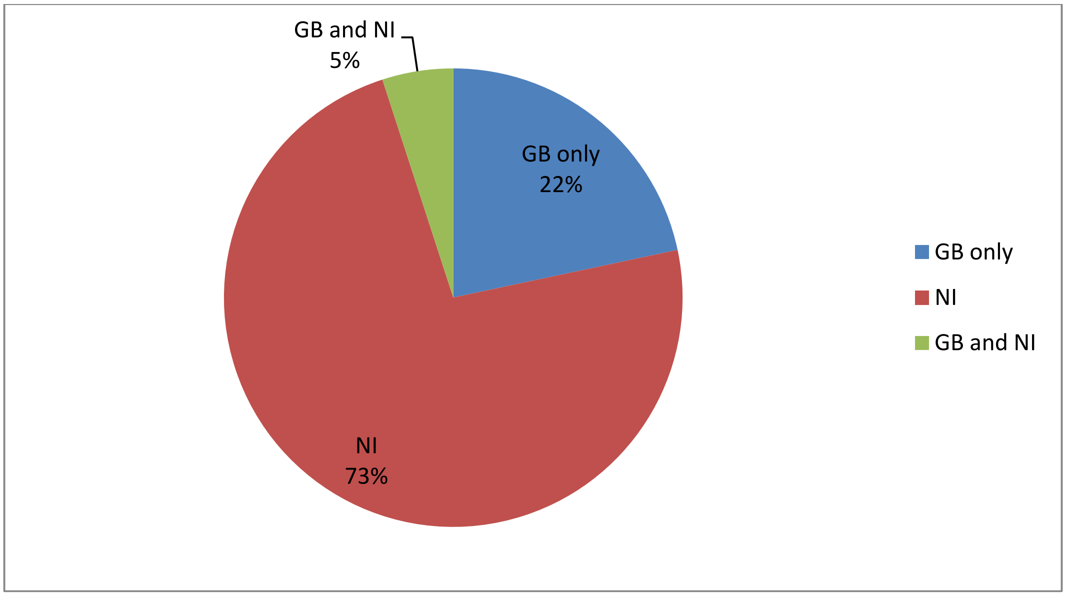

Figure 6.2 - Country of organisation of selected 60 respondents

The composition of each category out of the 60 responses analysed is as Figure 6.2; 73% from NI and 27% from GB or UK (that is GB and NI). The rest of the chapter is based on these 60 responses. Correlation analysis via SPSS was done for all questions discussed below. However, they are not referred to in questions where no correlations emerged.

6.5.2 Respondents' involvement in supply chains

The mean for this question was 2.15 with a standard deviation of 0.971. The mean and median for the question were both 2.00, where '2' represents 'moderate involvement in SCs'. The scale was a 4 point Likert scale where 1=High involvement in SCs and 4=Not much involvement in SCs. A total of 68.3% of the respondents, out of 60, have identified themselves as highly involved or moderately involved in SCs, another 20% as adhocly involved in SCs and the rest of the 11.7% as not much involved in SCs (refer Fig. 6.3). It appears that professionals who are not much involved in construction SCs are not inclined to respond to the survey, which reconfirms a significant reason for the low response rate for the survey as the number of professionals who are involved in SCM in the construction industry is still very low.

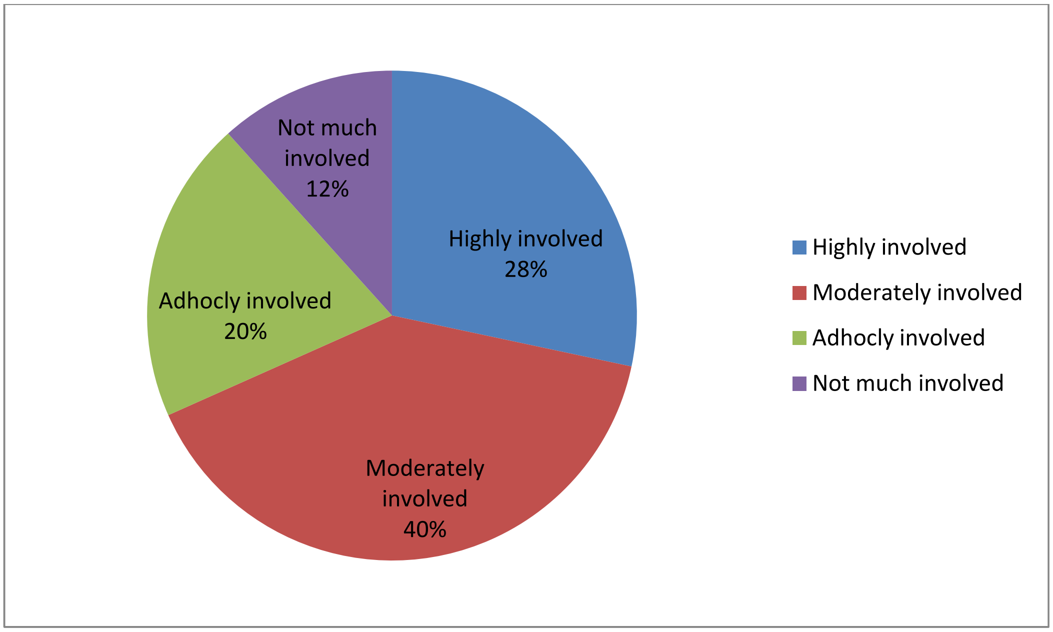

Figure 6.3 - Respondents' involvement in SCs

6.5.3 Respondents' level of expertise in supply chain management

The mean for the question was 3.18 with a standard deviation of 1.097. The mode and median for the data is also 3.0, which refers to a 'good' level of expertise in SCM. The scale for the question was a 5-point Likert scale where 1 refers to a 'poor' level of expertise and 5 refers to an 'excellent' level of expertise in SCM. Out of the 60 respondents 6.7% claimed a poor level of expertise, 20.0% a satisfactory level of expertise and the rest of the 73.3% has claimed a good, very good or excellent level of expertise (refer Fig. 6.4). The approximately 70% proportion of good or better level of expertise coincides with the proportion of respondents who are moderately or highly involved in SCs (68.3%). The Pearson correlation is also significant (0.583, p=0.000) for the relationship between level of involvement in SCs and expertise in SCM. Obviously, the construction professionals who are more involved in SCs, feel that they have more expertise in construction SCM. However, there is indication that some respondents claim a high level of expertise with a relatively low level of involvement in SCs. These are probably the late respondents, according to previous analysis of early and late respondents (refer section 6.4.4). This deduction is based on the fact that a higher percentage of respondents (73.3%) have claimed a high level of expertise when only 68.3% have claimed a moderate or a high involvement in SCs.

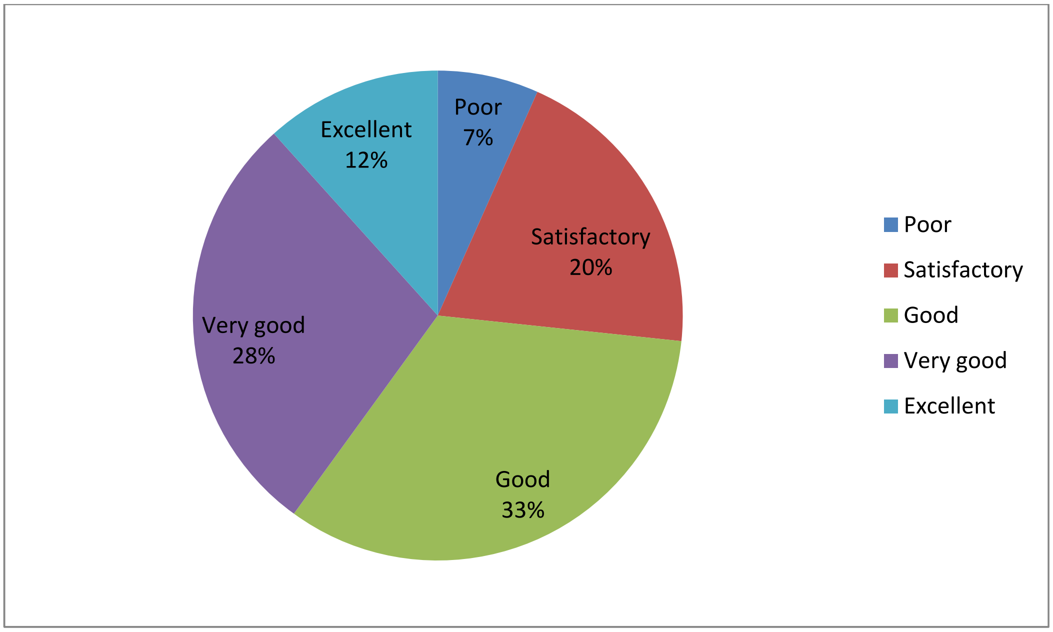

Figure 6.4 - Respondents' level of expertise in SCM

6.5.4 Turnover of respondents' organisations

Out of the 60 selected respondents, 59 have responded to this question. The percentages presented in Figure 6.5 have been adjusted via SPSS for the missing response. Most responses (39%) were received from large organisations (based on turnover, as classified according to EU regulations), closely followed by (36%) small and micro organisations (organisation with a turnover less than 10 million Euros). The medium sized organisations accounted for the rest of the 25% of responses.

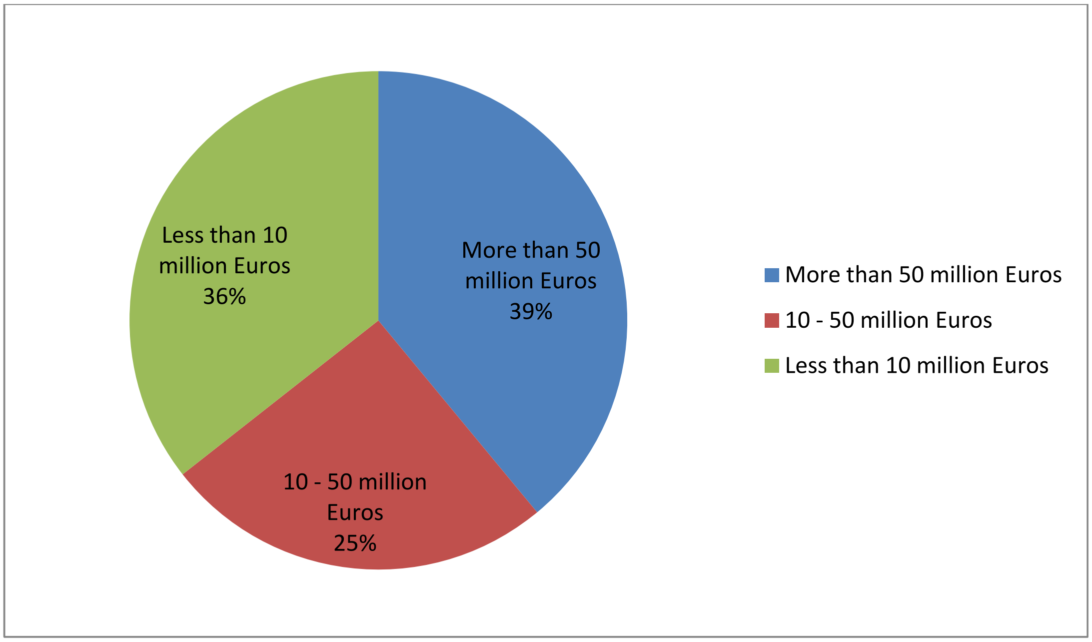

Figure 6.5 - Turnover of respondents' organisations

There is a low correlation (0.392, p=0.002) between turnover of an organisation and the level of involvement in SCs according to Cohen and Holliday's (1996) rough and ready guide on interpretation of correlation coefficients. The Delphi survey also indicated that large contractors were more likely to respond than small or medium sized contractors, due to their perceived higher involvement in SCs. This finding is confirmed from the e-survey, although the differences in percentages of large and small organisations are not very significant as in the Delphi survey. This is possibly due to the high response rates from organisations which have high interest (and involvement) in SCM, although not high expertise as would have been necessary to respond to the Delphi survey. There is no significant correlation between expertise of respondents and the turnover of organisations, although there was a significant correlation (0.583, p=0.000) between expertise of respondents and the level of involvement in SCs. Thus the precedence is probably that the turnover or the size of an organisation influences, albeit slightly, the level of involvement in SCs, and then involvement in SCs has some impact on the level of expertise of respondents (which was not observed in this scenario due to the correlation being low between turnover and involvement in SCs).

6.5.5 Size of organisation of respondents

Out of the 60 selected respondents, 59 have responded to this question. The percentages presented in Figure 6.6 have been adjusted via SPSS for the missing response. Most responses (42%) were received from large organisations (based on number of employees, as classified according to EU regulations), closely followed by (39%) small and micro organisations (organisation with a turnover less than 10 million Euros). The medium sized organisations accounted for the rest of the 19% of responses.

There are differences in the percentages for the 3 different sizes of organisations based on turnover and number of employees. Some discrepancies such as this would be expected in a survey and in classification according to the EU regulations. Yet the order of the large organisations responding most, closely followed by small organisations remains the same as for the previous question. The question did not show any correlations with level of expertise of respondents or involvement in SCs. After all, there was only a low correlation with involvement in SCs and turnover of an organisation as explained in section 6.5.4.

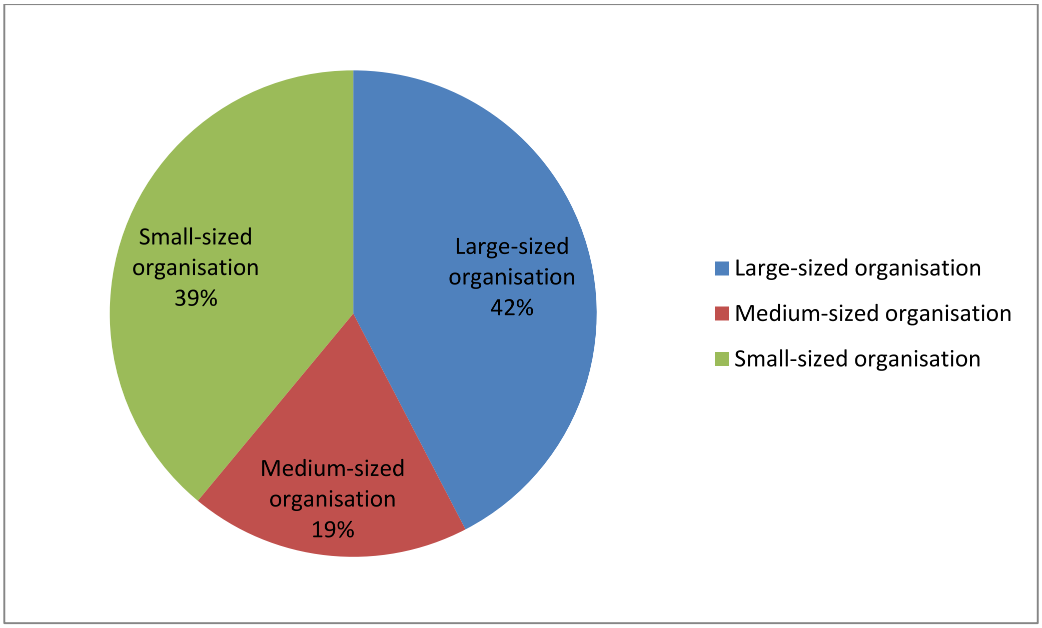

Figure 6.6 - Size of organisation of respondents

6.5.6 Types of organisation

The lowest number of responses was received from consultancy organisations, despite being sent more reminders than clients, suppliers and subcontractors (due to them being contacted first). The consultancy organisations included the disciplines architecture, engineering, quantity surveying and project management. The front end (Tier 1/ Clients) and the rear end (Tier 4/ Suppliers and Subcontractors) of the SC have responded at 27% and 25% respectively, despite being reminded much less than contractors or consultants (due to being contacted last). So it appears that they have a high interest in SCM. The main contractors and organisations associated with main contracting and additional functions, such as developers, project managers, design, etc., accounted for the rest of the responses (33%). The Delphi survey too recorded the highest number of responses from the contractors. The main difference between the e-survey and the Delphi survey was that the suppliers (Tier 4) responded almost as the clients and more than the consultants. This may be because suppliers have a high interest in SCM, but not a high level of expertise to respond to a Delphi survey.

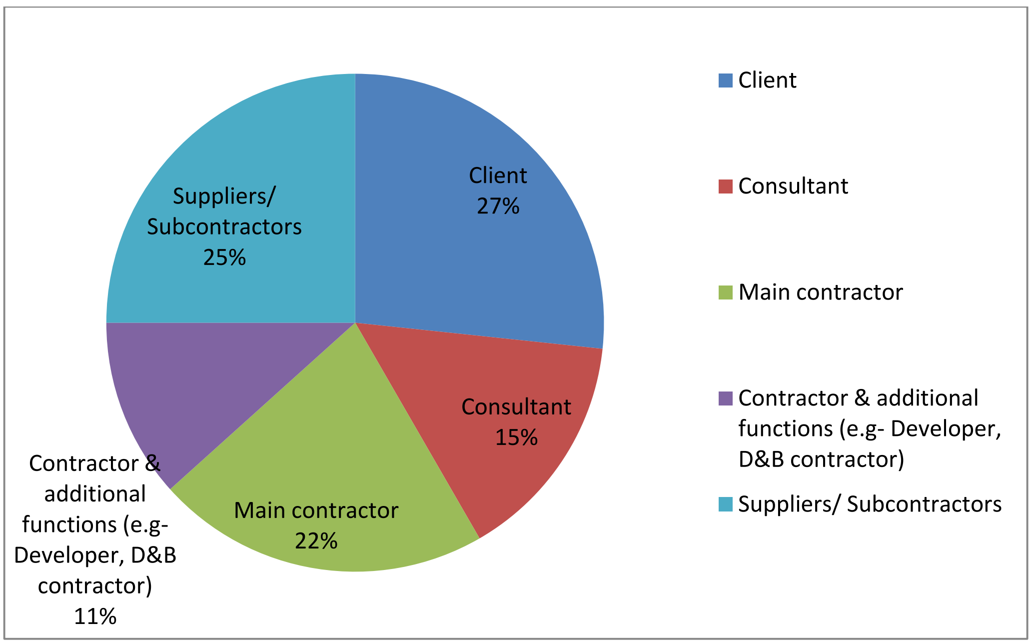

Figure 6.7 - Categories of respondents (by type of construction organisation)

6.6 Analysis of Section B - Assessment of the level of integration of construction supply chains via the proposed SCM framework

Section B of the questionnaire requested respondents to assess their current and future level of integration, based on the 13 CSFs, using the proposed SCM framework. The framework included four levels of integration; namely Level 1 – Minimal integration, Level 2 – Internal integration, Level 3 – Some external collaboration and Level 4 – Extensive external collaboration. The questions for this section were compulsory; however, respondents were given the option of selecting ‘Not applicable/ Don’t know’ for a question if they could not select a level of integration based on the SCM framework. All questions in section B were tested for correlations with general information such as type of organisation, size of organisation, etc. gathered in section A, via SPSS. There were no significant correlations. However, it should be recognised that these results are based on a framework which is not yet evaluated. These results are only a by-product of the evaluation process. The CSFs are discussed in the order they appeared in the framework; that is the order of priority as confirmed in the Delphi survey.

6.6.1 CSF 1 – Positive attitude and approach to working relationships

The responses have varied from Level 1 across to Level 4, with a mean of 2.78 and standard deviation of 0.825, according to SPSS analysis. The mode for this CSF is 3, where Level 3 refers to a level of integration which expands beyond the focal organisation, to a few external organisations. 43% of the respondents have identified themselves to be in Level 3 with regard to their current level of integration, and 32% as in Level 2 (refer Fig. 6.8). One fifth of the respondents have identified their organisations to be in Level 4 already, which is the highest level of integration identified in the proposed SCM framework. Only 3 out of 60 respondents, that is 5%, have identified Level 1 as their current level of integration.

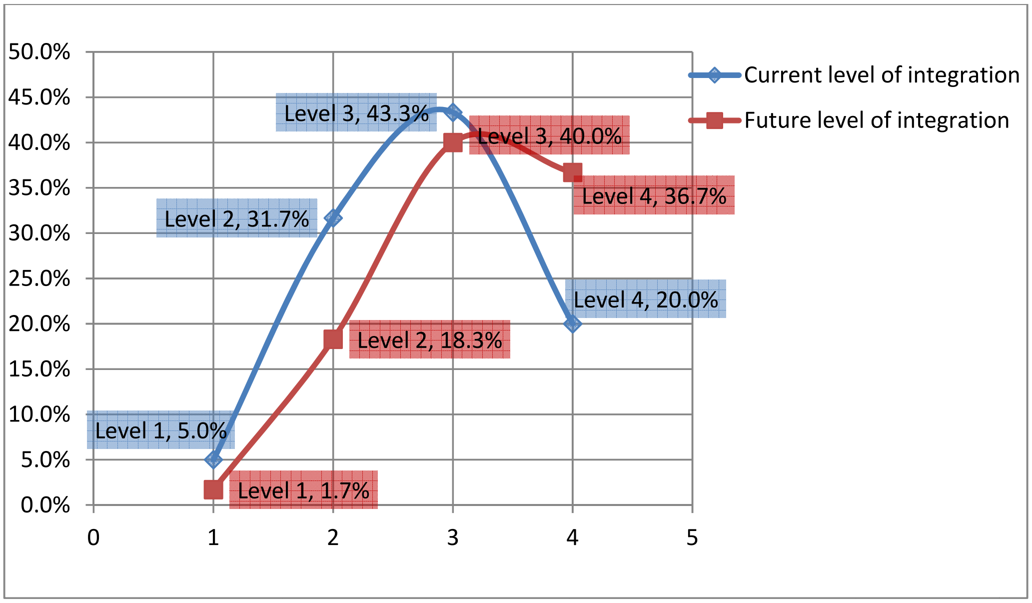

Figure 6.8 - Levels of integration for CSF 1

There is a slight drop (3%) in Level 1 and Level 3 from current to the anticipated level of integration in 3-5 years, whilst the drop in Level 2 is significant (14%). Level 4 has indicated significant improvement where it has jumped from 20% of respondents at the current time, to 37% of respondents in the future. So it appears that there is an expected transition from lower levels of integration to higher levels of integration in the future, where the number of organisations moving from Level 1 to Level 2 is surpassed by the number moving from Level 2 to Level 3, and that number is further surpassed by the transition from Level 3 to Level 4, in the anticipated future years. Nevertheless some organisations/respondents do expect ‘revolutionary’ improvements rather than ‘evolutionary’ improvements where they expect to skip a level to the next level, for example from Level 2 to Level 4.

All respondents have been able to identify their current level of integration for this CSF, whilst 2 respondents (3.3%) have not identified their future level of integration. It is acceptable that some respondents will find it difficult to determine their future level of integration with regard to some CSFs.

6.6.2 CSF 2 – Support and commitment of leaders/ senior management of all supply chain member organisations towards integrated supply chains

All 60 respondents have responded to the question current level of integration for CSF 2. The mean is 2.75, with a standard deviation of .704. The mode is 3, which relates to Level 3; a level of integration where the SCM concept expands beyond the focal organisation, to embrace a few external organisations.

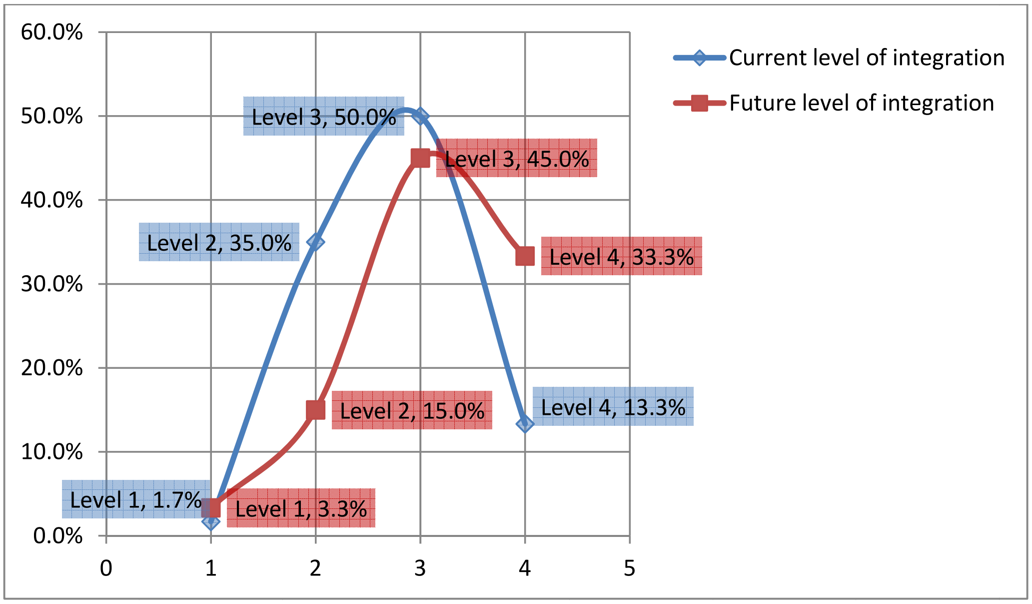

Figure 6.9 - Levels of integration for CSF 2

The question with regard to the future level of integration for the same CSF has received 2 responses (3.3%) which state that they cannot predict the matter (refer Fig. 6.9). The other 58 respondents have claimed 3.3%, 15%, 45% and 33.3% for Level 1, 2, 3 and 4 respectively for the future level of integration with regard to CSF 2. This is an increase of 20% for Level 4, and a decrease of 5% and 20% from Level 3 and 2. The decreases from Level 2 and 3 are due to the shifting of organisations towards Level 4.

Moreover, 2 respondents (3.3%) have identified themselves to be in Level 1 in the future. One of them had identified his/her organisation to be in Level 1 at present time. Hence he/she expects no improvement. This is a respondent from a small client organisation. The other respondent, who belongs to a medium sized supplier organisation, expects his/her organisation to move from Level 2 to Level 1 in 3-5 years. They have not provided comments to understand their situation any further. Moreover, they have described the framework as moderately easy to use and somewhat useful in assessing and improving SCs. It is noteworthy that some other respondents have commented that in the current economic climate, where we have experienced economic downturn for several years without much hope for improvement, concepts such as SCM is becoming hard to embrace and practice.

6.6.3 CSF 3 – Level of trust between supply chain members

The modes for both the graphs remain Level 3 (see Figure 6.10). Only 3.3% of organisations claim to be at Level 4 at present with regard to level of trust between SC members. This is the lowest percentage compared with other 12 CSFs. This phenomenon, lack of trust in the construction industry, was identified in literature. However, there is a significant shift from Level 3 to Level 4 from the current to future level of integration, where the total percentage of organisations for Level 4 increases from 3.3% to 26.7% in 3-5 years. This is a significant positive outlook for the construction industry. This CSF generates the highest improvement at Level 4, from current to future levels of integration.

The number of respondents who claimed that they cannot assess their level of integration with regard to the level of trust between SC members is one, for the assessment of current level of integration, and two for the future level of integration. The respondent who has claimed that he cannot assess the current level of integration has also claimed later that even though the framework is somewhat easy to use he does not find the framework sufficiently descriptive enough to understand improvements. This respondent belongs to a small-medium sized client organisation, and has categorised himself as having poor expertise in SCM and as not being much involved in SCs. Hence there may be the necessity to add further descriptions or examples for users of less SCM expertise to help them use the framework.

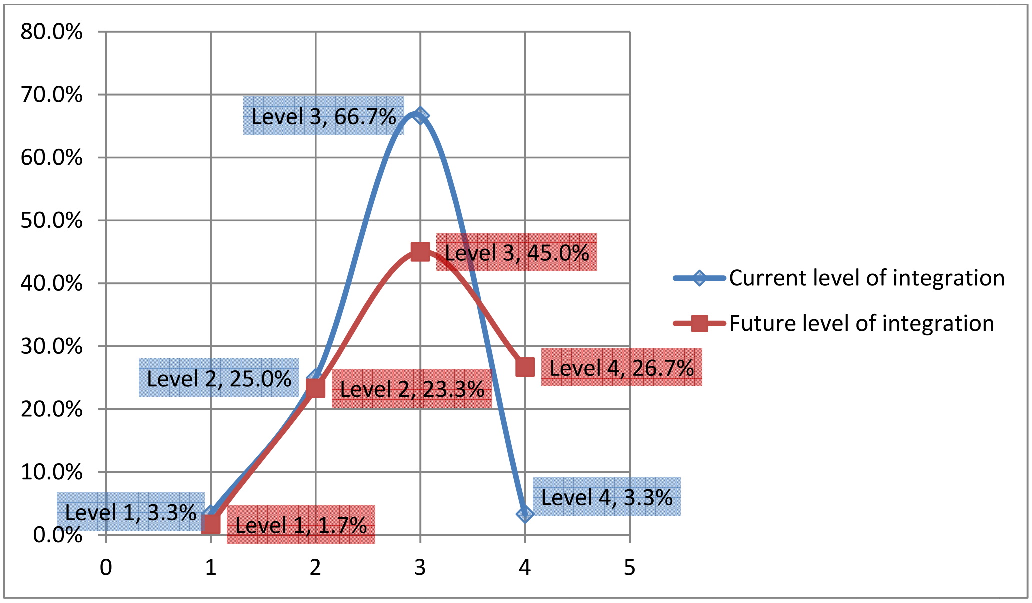

Figure 6.10 - Levels of integration for CSF 3

6.6.4 CSF 4 – Extent of communication between supply chain members

The mode for CSF 4 also is 3, with 53.3% responding that level 3 is where their organisations currently are. The current and future levels of integration, across the 4 levels, are shown in Figure 6.11. The significant shift is from Level 3 to Level 4, where organisations in Level 4 increase from 13.3% to 33.3% from current to future times. The shift from Level 1 to 2 or from Level 2 to 3 is negligible, where there are 31.7% organisations in lower levels (Levels 1 and 2) of integration currently and 28.4% in 3-5 years. Similarly there are 66.6% organisations in higher levels of integration (Level 3 and 4) currently and 68.3% in 3-5 years. The change overall in higher levels of integration is not significant, because the upward shift is only from organisations who are currently at Level 3.

One respondent has not identified their current level of integration for this CSF based on the framework, and two have claimed that they do not know their future level of integration. The respondent who has not identified his/her current level of integration is the same respondent identified under CSF 3, from a small-medium sized client organisation, who is not much involved in SCs and claims not to have much SCM expertise.

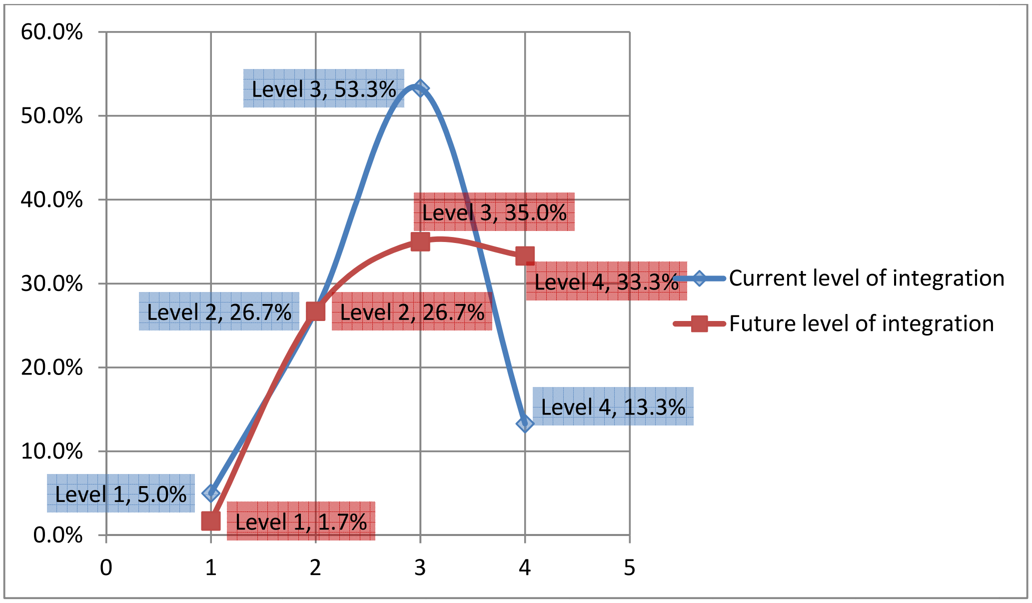

Figure 6.11 - Levels of integration for CSF 4

6.6.5 CSF 5 – Degree of collaboration, between supply chain members, when making key decisions

The mode for this CSF is 2, where 41.7% have identified their current level of integration as Level 2. This is closely followed by responses for Level 3 (36.7%). The number of responses for Level 4 for CSF 5 is 16.7%. However, when asked to predict their level of integration in the future, 36.7% have predicted that their organisation will belong to Level 4 in 3-5 years, which is a 20% increase. Most CSFs demonstrated a 20% increase at Level 4 from current to future levels.

The curve for future levels of integration for CSF 5 (refer figure 6.12) is somewhat different from the previous CSFs. This is due to the fact that the predicted percentage for Level 4 (36.7%) is higher than the percentage for Level 3 (33.3%), whilst all other CSFs discussed have a lower percentage for Level 4 than at Level 3. This may be possible due to software such as BIM allowing sharing of information to make real-time collaborative decisions.

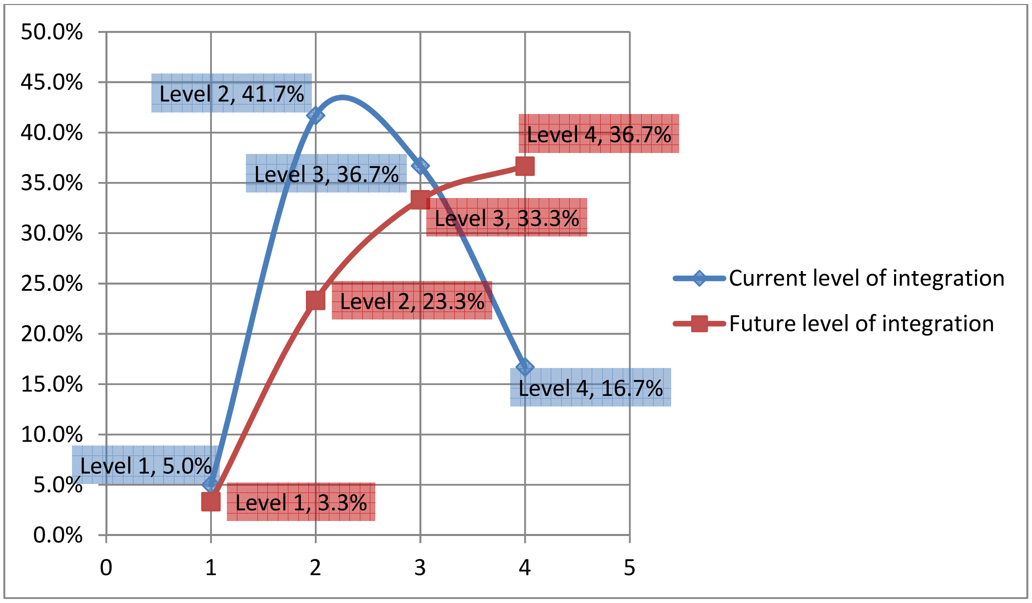

Figure 6.12 - Levels of integration for CSF 5

All respondents have been able to identify a current level of integration for their organisation using the SCM framework. There are 2 respondents (3.3%) who have not identified a future level of integration for this CSF, which is quite similar to other CSFs.

6.6.6 CSF 6 – Availability of a vision, mission, strategy, policy and procedures for management of supply chains

The percentages of responses per level of integration for both questions, current and future levels of integration, are presented in Figure 6.13. The mode for the current level of integration for CSF 6 is Level 2, at 40% and the mode for the future level of integration is Level 3, at 41.7%. Two respondents (3.3%) have not identified their organisation's future level of integration. One respondent (the same respondent identified earlier from a small-medium sized client organisation, who is not much involved in SCs and claims not to have much SCM expertise) seemed unable to select a current level of integration.

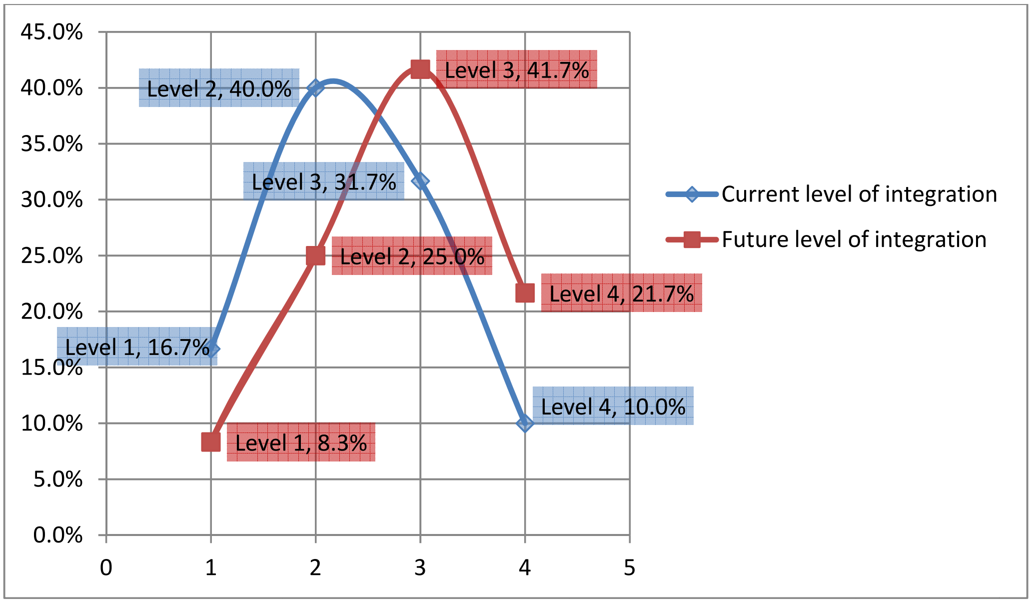

Figure 6.13 - Levels of integration for CSF 6

There is a similar increase and reduction of respondents across the four levels of integration from current to future level of integration. There is a 23.3% reduction of organisations belonging to Level 1 and 2 from current to future levels of integration and an increase of 21.7% in Level 3 and Level 4. The improvement of organisations at Level 4 for this CSF is somewhat low when compared with other CSFs.

6.6.7 CSF 7 – Availability and use of IT for collaboration between supply chain members

The percentages of responses per level of integration for both questions, current and future levels of integration, are presented in Figure 6.14. The mode for current level of integration is Level 2 (43.3%) and the mode for future level of integration is Level 3 (50.0%). There are only 8.3% respondents who claim to be at Level 4 of integration currently. However a quarter of the organisations expect to move to Level 4 in 3-5 years. This is an average improvement in comparison to other CSFs. However, 50% of the organisations expect to be at Level 3 in 3-5 years. This is a very high percentage in comparison to other CSFs. Fewer than 25% of organisations expect to remain in Level 1 and 2, in 3-5 years, with regard to collaborative IT provisions within their organisations. One respondent (1.7%) stated that he/she cannot identify the level of integration with regard to both current and future level of integration. This is a very important CSF with regard to SCM, particularly in the manufacturing industries. This is due to the recognition that IT provides the infrastructure to have shared databases, improved communication and real-time decision making. However, construction professionals do not seem to have recognised such an importance with this CSF (in contrast to CSF 3, which recorded the highest improvement at Level 4). Yet it has shown a very high number of organisations (50%) striving to be at Level 3 in comparison to other CSFs. It is not clear if respondents find Level 3 a more feasible stage for construction organisations than Level 4, or whether they perceive more time required for more organisations to move to Level 4. It should be noted here that it could be the case that investment in IT may need to be limited, if it is realised that an organisation constantly deals with short-term projects which essentially have short payback periods, which does not permit high investments in IT.

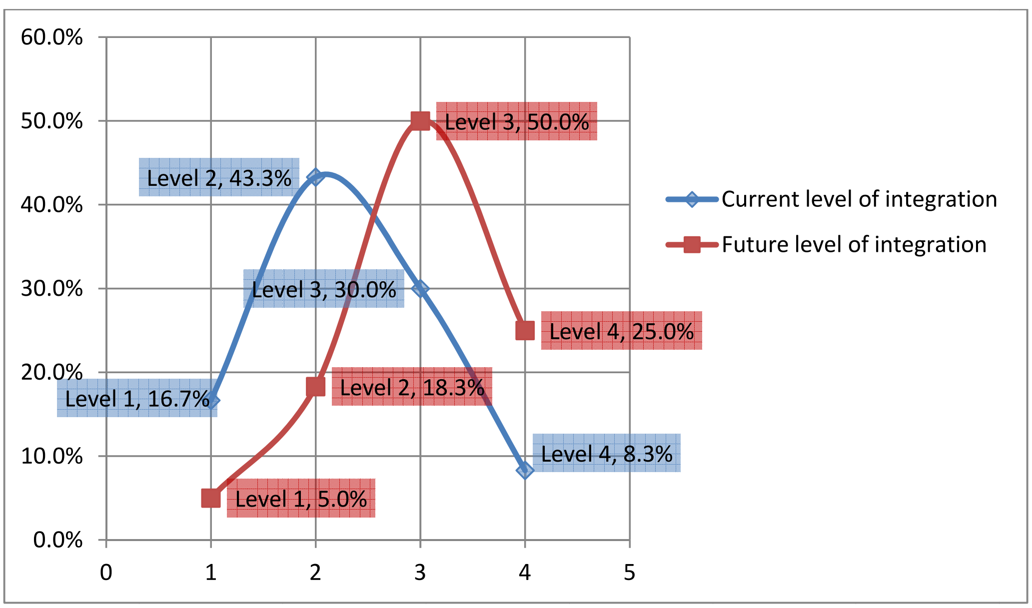

Figure 6.14 - Levels of integration for CSF 7

6.6.8 CSF 8 – Existence of a protocol for conflict resolution among supply chain members

The percentages of responses per level of integration for both questions, current and future levels of integration, are presented in Figure 6.15. The mode for CSF 8 is Level 2 for the current level of integration and Level 3 for the future level of integration. 60% of organisations belong to Level 1 and 2 for current level of integration and 35%

of organisations belong to Level 3 and 4, whereas respondents predict that in 3-5 years as much as 65% of organisations will belong to Levels 3 and 4 and only 31.6% to belong to Levels 1 and 2.

Three (5%) respondents have not identified their current level of integration whilst two (3.3%) have not identified their future level of integration. Two respondents who have not been able to identify his/her current level of integration have been able to identify the organisation's future level of integration. This is one of the two CSFs where respondents (even though very few) have responded more number of times regarding the future level of integration than the current level of integration. It may be that respondents are not aware if there is a protocol for conflict resolution among SC members at present; however, they hope that in 3-5 years such as protocol would be in place. These respondents have not provided any further comments; hence it is not very clear as to why they have responded as such.

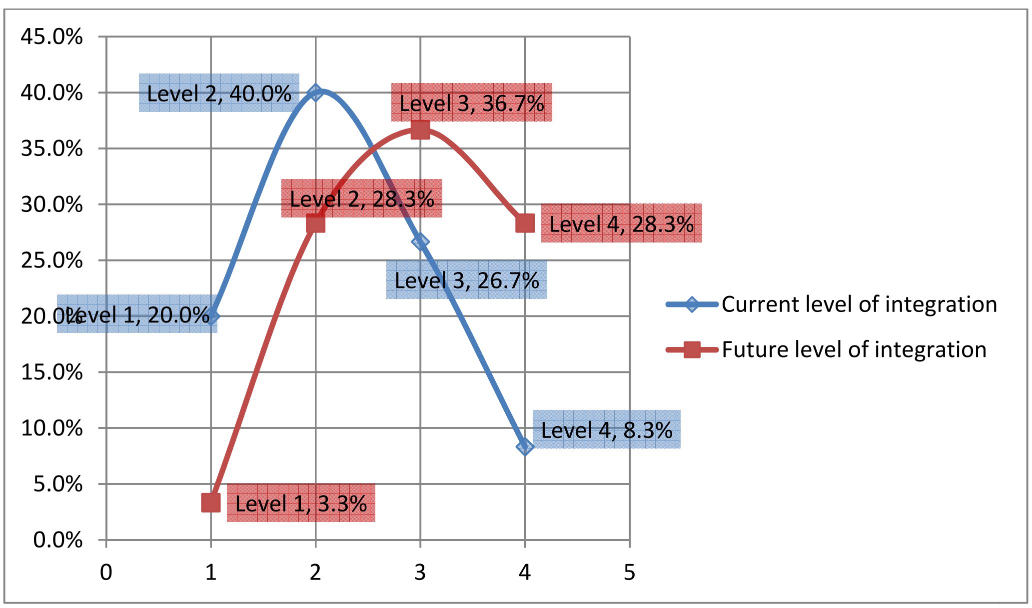

Figure 6.15 - Levels of integration for CSF 8

6.6.9 CSF 9 – Existence of a system to measure performance of supply chain members

The percentages of responses per level of integration for both questions, current and future levels of integration, are presented in Figure 6.16. For the first question, current level of integration, 16.7% categorised their organisation as Level 1 with regard to CSF 9, 31.7% as Level 2, 33.3% as Level 3 and 16.7% as Level 4. Thus there is a similar spread of organisations across the two lower levels and the two higher levels of integration. However, for the future level of integration there is a significant shift from the current level of integration where just over a quarter of organisations (26.7%) expect to remain in the lower levels of integration, whilst 70% of the organisations expect to be in the two higher levels of integration. There is one respondent (1.7%) who has not identified the current level of integration and two (3.3%) who have not identified the future level of integration.

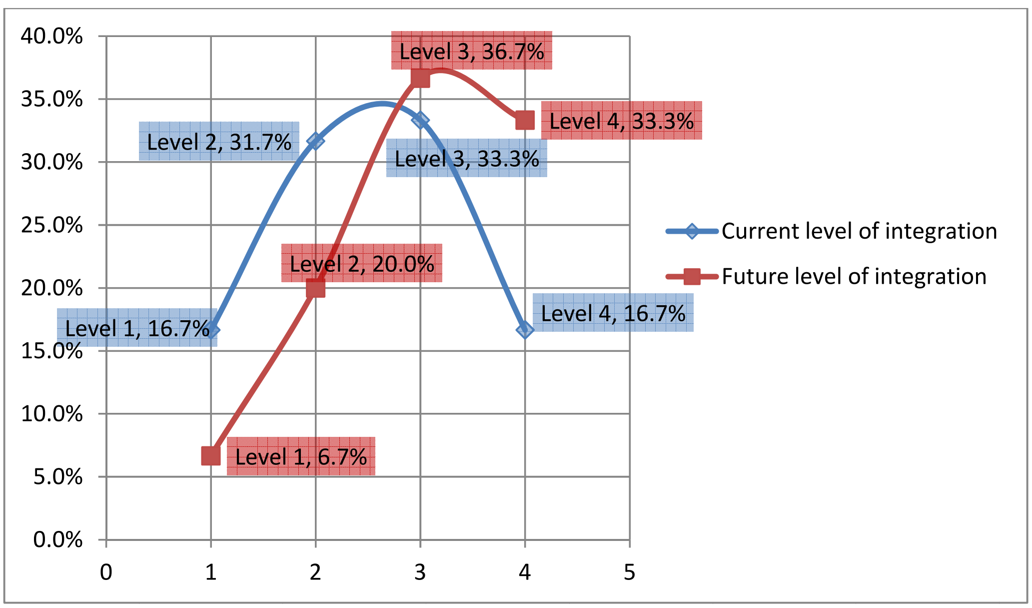

Figure 6.16 - Levels of integration for CSF 9

6.6.10 CSF 10 – Procurement methods used to procure projects

The percentages of responses per level of integration for both questions, current and future levels of integration, are presented in Figure 6.17. The mode for both current and future levels of integration is Level 3. There are 38.4% organisations in Level 1 and 2 currently, and only 18.3% in Level 1 and 2 in 3-5 years whilst there are 61.7%

organisations in Level 3 and 4 at present and 80% of organisations expect to be in Level 3 and 4 in 3-5 years. Most respondents seem confident in selecting a level of integration for this CSF, with only one respondent not selecting a level for their future level of integration. This respondent has not selected a future level of integration for any of the CSFs.

The procurement methods in the lower levels of integration are driven by low price, whilst at higher levels of integration procurement is driven by price and quality. At Level 4 CSF 11 is described in the framework as 'Procurement methods promote partnering, long-term collaboration, performance related payment and open-book accounting. The SC demonstrates good understanding of all types of procurement methods. The procurement strategy is developed by all SC members to suit projects, and there is commitment to key SC members for long-term partnerships.' However, the improvement at Level 4 from current to future level of integration is less than the average improvement for this CSF, similar to CSF 11.

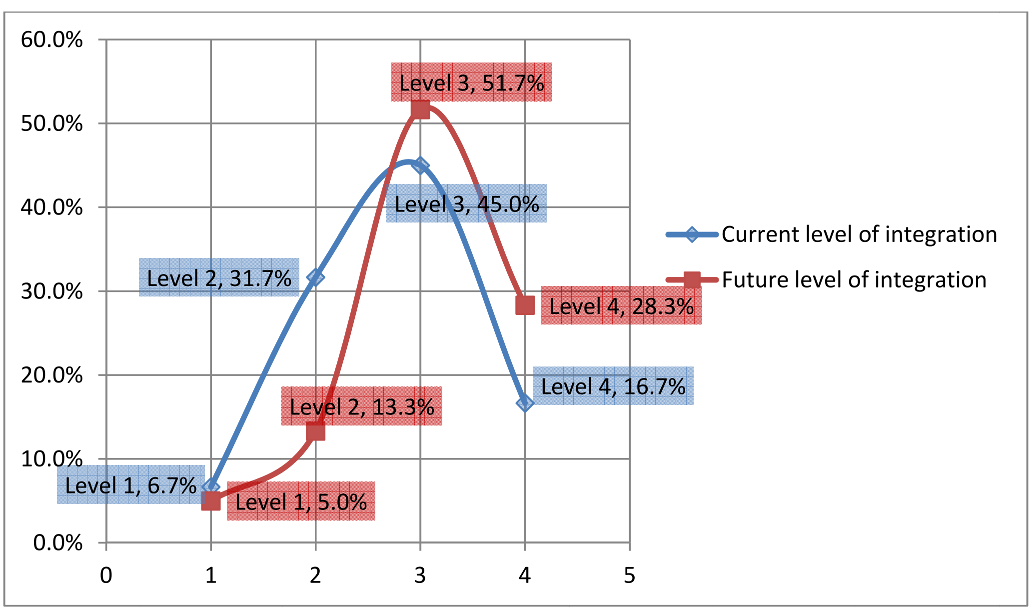

Figure 6.17 - Levels of integration for CSF 10

6.6.11 CSF 11 –Length of project duration or Continuity of work to sustain the supply chain

The percentages of responses per level of integration for both questions, current and future levels of integration, are presented in Figure 6.18. The mode for both current and future level of integration of organisations with regard to CSF 10 is Level 3 with 50% -53.3% of organisations remaining in Level 3. However, there is a significant shift from 5% to 18.3% at Level 4 from the current to the future level of integration, and a shift from 43.3% to 25% organisations in Level 1 and 2. There is one respondent (1.7%) who has not identified the current level of integration and two (3.3%) who have not identified the future level of integration.

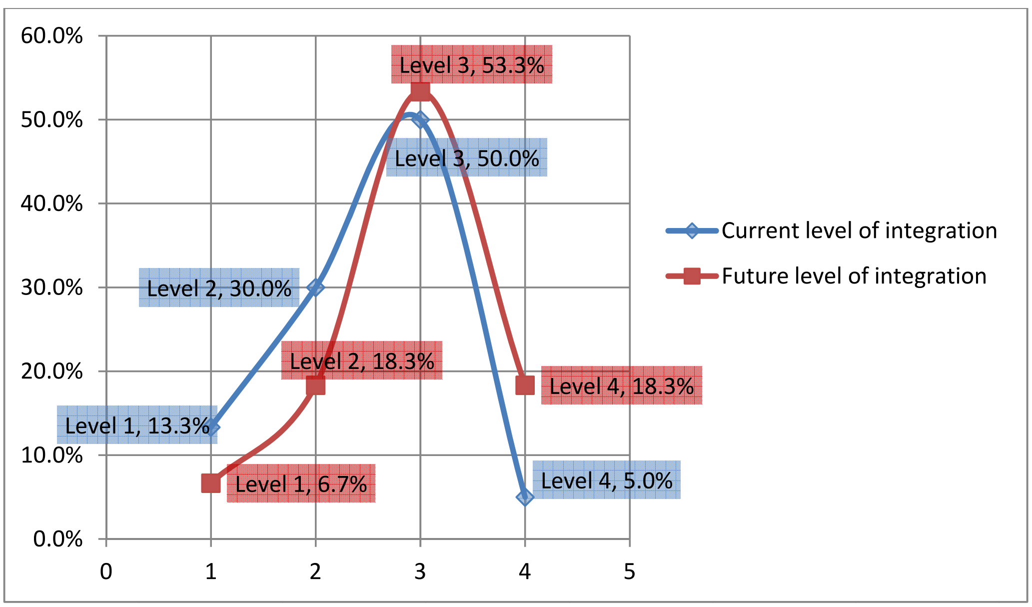

Figure 6.18 - Levels of integration for CSF 11

The predicted percentage (18.3%) and the current percentage (5%) for Level 4 are very low in comparison to other CSFs. This CSF also records a low improvement from current to future levels of integration in comparison to other CSFs. Thus it can be concluded that the length of the project duration or continuity of work to sustain the SC would see one of the lowest improvements in the future in comparison to the rest of the 12 CSFs. This is to be expected as procurement methods have an impact on continuity work, and procurement methods that promote continuity of work such as framework contracts is not suitable for most clients and construction projects.

Level 4 expects that a formal contractual commitment to continuity of work and long-term relationships exists with SC members. For most construction projects this would not be feasible due to the one-off nature of construction projects. Hence Level 3 would be the highest level that is attainable by most projects; that is where, according to the description in the proposed framework, ‘There will be some successful collaboration with long-term projects and repeat projects. There will be informal commitment to key SC members regarding possible continuity of work. Indication of further work will be based on good performance’.

6.6.12 CSF 12 – Promoting engagement of all supply chain members at the client briefing stage

The percentages of responses per level of integration for both questions, current and future levels of integration, are presented in Figure 6.19. The mode for both current and future level of integration is Level 3. At the assessment of the current level of integration 48.3% of organisations belonged to Level 1 and 2, and 51.6% belonged to Level 3 and 4. That is somewhat an equal spread of organisations among lower and higher levels of integration. At the assessment of the future level of integration less than a quarter (23.4%) of organisations belonged to Level 1 and 2 and 71.7%belonged to Level 3 and 4, where the number of organisations at Level 4 is expected to increase over 3-5 years from 13.3% to 30.0%. Three (5%) respondents have stated that they cannot predict their future level of integration with regard to CSF 12, whilst all have been able to identify a level of integration for the assessment of the current status of their SCs.

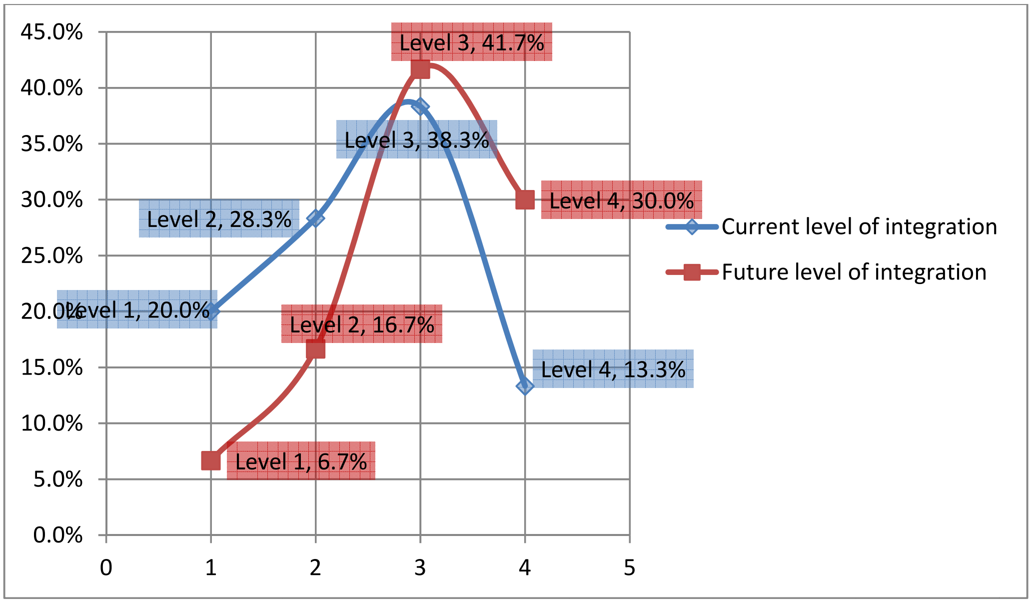

Figure 6.19 - Levels of integration for CSF 12

6.6.13 CSF 13 – Existence of a strategy for training and development of supply chain members

The percentages of responses per level of integration for both questions, current and future levels of integration, are presented in Figure 6.20. The curve for the current level of integration for CSF 13 behaves quite differently to the other CSFs. The mode for the current level of integration for CSF 13 is Level 1, with 35.0% of organisations at Level 1, 31.7% at Level 2, 25.0% at Level 3 and 8.3% at Level 4. All of the respondents were able to select a current level of integration for this CSF.

However, the predictions for organisations in 3-5 years for CSF 13 are quite similar to the rest of the CSFs. The mode for the future level of integration is Level 3, with 30% of organisations expected to remain in Level 1 and 2, whilst 65% expect to progress to Level 3 and 4. This demonstrates that respondents consider training and development of SC members an important CSF, which is implied by the fact that they expect to achieve some improvement in 3-5 years even though most organisations are at Level 1 at present. Yet most improvements are up to Level 3. In comparison to other CSFs, Level 4 records the lowest improvement from current to future level of integration and the lowest percentage for future level of integration. After all, this should be expected, since this is the lowest prioritised CSF in the Delphi survey.

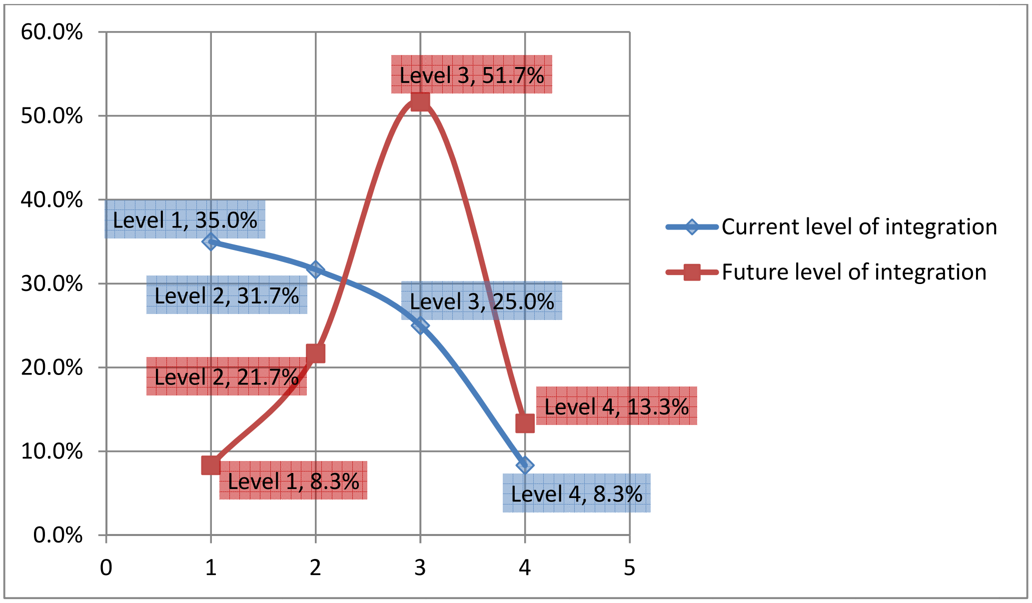

Figure 6.20 - Levels of integration for CSF 13

6.7 An overview of the current level of integration for all 13 critical success factors

The current level of integration for most organisations is Level 2 or 3 (see Figure 6.21). The percentage of organisations belonging to Level 4 is 20% or less for all of the 13 CSFs. The CSF with the highest percentage of organisations for level 4 currently is CSF 1: 'Attitude and approach to working relationships'. This is in contrast to previous literature which states that there are considerable attitudinal problems in the construction industry (refer chapter 1 and 2). This may be due to the improvements in the industry over the years, or it could be attributed to the biased nature of organisations who would respond to this type survey - that is organisations who appreciate collaboration.

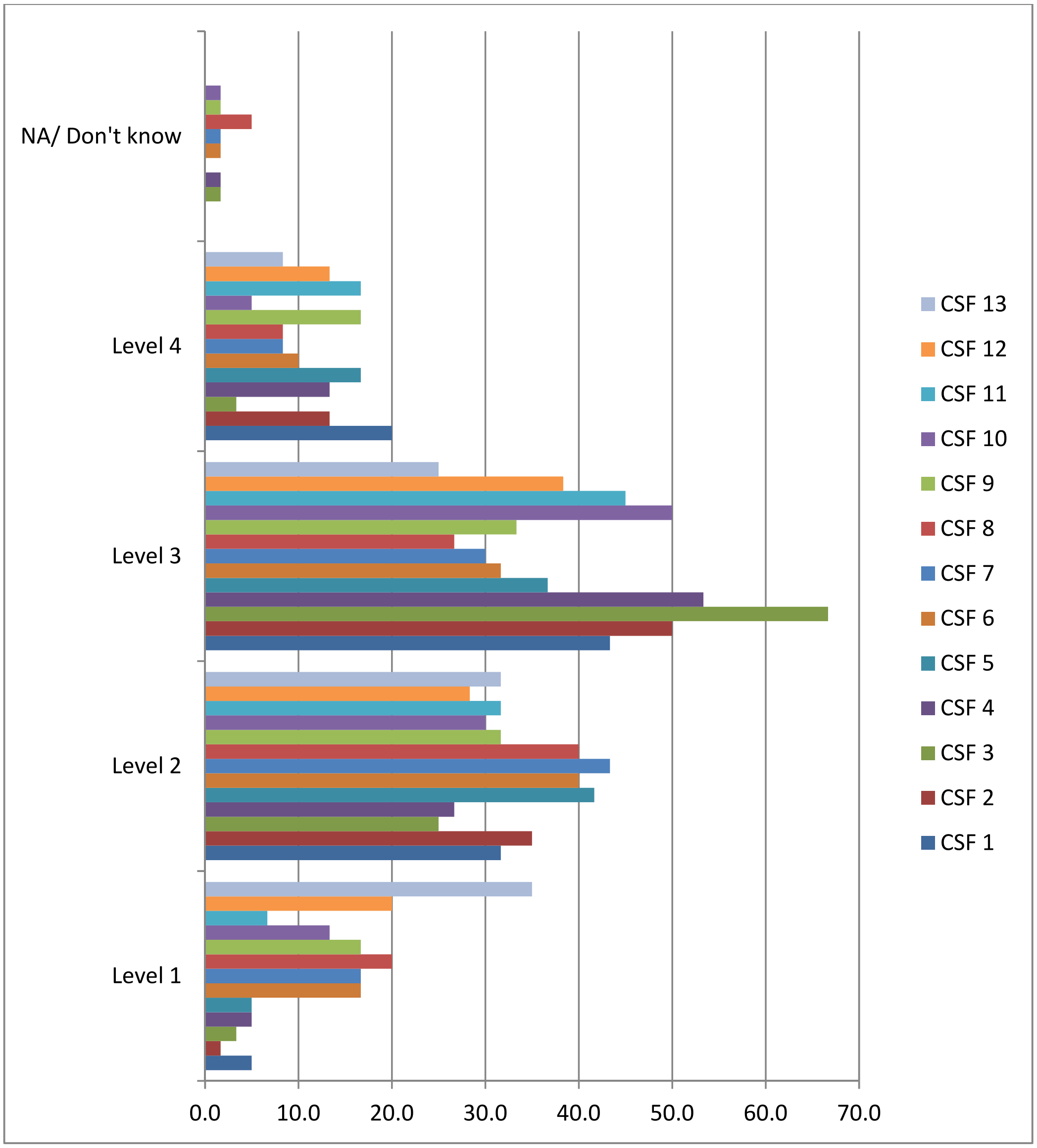

Figure 6.21 - Analysis of the current level of integration of construction SCs (based on percentage responses for the 13 CSFs)

In contrast to the results for CSF 1, CSF 3 'Level of trust between SC members' achieved the lowest percentage of organisations at Level 4 (3.3%). This is as acknowledged in previous literature. However, this CSF achieves the highest improvement with an increase of 23.4% organisations at Level 4 in future. Hence the industry seems to acknowledge the importance of trust.

The CSF with the second lowest percentage of organisations (5%) at Level 4 for current level of integration is CSF 10: Minimum length of project duration or

Continuity of work to sustain the SC. The improvement of this CSF in future is also below average, in comparison to other CSFs. This is probably due to the one-off nature of construction projects, and most clients not being able to offer continuity of works. This problem will continue to affect the construction industry, making it difficult to exercise all SCM practices of the manufacturing industries.

The number of responses claiming inability to identify a current level of integration is 0% for 6 of the CSFs, 1.7% (1 response) for another 6 of the CSFs and 5% (3 responses) for one CSF (CSF 8 - Existence of a protocol for conflict resolution among SC members). 0% - 1.7% is a very low range of percentages which allows the descriptions of the SCM framework to be validated as clear, relevant and easy to understand by professionals of the UK construction industry (except for CSF 8). With regard to CSF 8, it is not clear as to why the respondents were unable to select a level of integration. It should be noted that a lower percentage of respondents (3.3%) claimed 'NA/ Don't know' for CSF 8 when questioned about their future level of integration. This suggests that the description for CSF 8 was not attributable to the higher percentage of 'NA/ Don't know' responses for this CSF when questioned on current level of integration; instead it seems to be the lack of knowledge of the existence of a protocol for conflict resolution as discussed under the section 6.6.8. It should be reminded that these validations are based on 60 responses from different tiers of the SC. Due to the target number of responses (refer 4.8.2) not being achieved it is not possible to derive any statistically reliable correlations between the results and categories of respondents.

6.8 An overview of the future level of integration for all 13 critical success factors

Although many organisations expect to improve their level of integration in 3-5 years, the modes for all CSFs, except CSF 5, remain Level 3 in the near future (see Figure 6.22). The mode for CSF 5 (Degree of collaboration, between SC members, when making key decisions), in 3-5 years, is Level 4. Based on generic SCM models, the researcher expected IT infrastructure to have comparable improvement. Yet CSF 7 (collaborative IT provision) only achieved average improvement. Hence it is unclear how these organisations who hope to achieve Level 4 for CSF 5 will achieve this without supporting IT infrastructure.

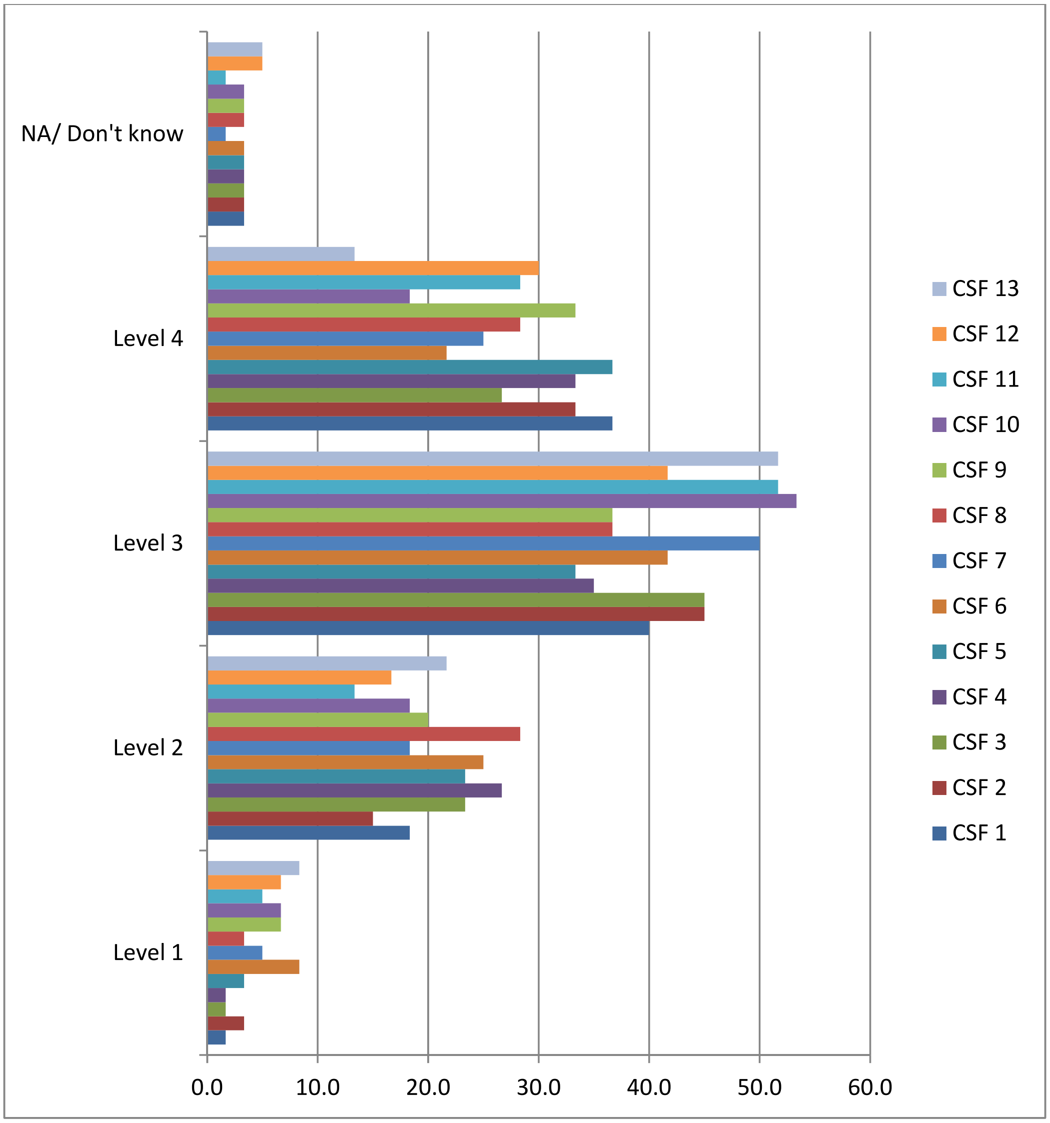

Figure 6.22 - Analysis of the future level of integration for construction SCs (based on percentage of responses for the 13 CSFs)

The CSFs that will achieve the highest number of organisations (36.7%) in Level 4 in 3-5 years are CSF 5 and CSF 1. CSF 1 (Attitude and approach to working relationships) obtained the highest percentage of organisations (20%) for Level 4 for the assessment on current level of integration. Hence this is an improvement of 16.7%. The improvement for CSF 5 will be 20% from its current level of integration. The researcher acknowledges that with the implementation of systems such as BIM, it would not be difficult to achieve such improvement in 3-5 years.

The CSF that will have the lowest number of organisations (13.3%) in Level 4, in 3-5 years, is CSF 13 ‘strategy for training and development’. However, it should be noted that this is an improvement as CSF 13 was the only CSF which received a mode of Level 1 when assessed on current level of integration. Moreover this is the lowest prioritised CSF in the Delphi survey. The CSFs that will have the highest number of organisations (8.3%) remaining in Level 1, in 3-5 years, would be CSF 6 and 13. The CSFs that will have the lowest number of organisations (1.7%) at Level 1, in 3-5 years, are CSFs 1, 3 and 4 (some of the highly prioritised CSFs during the Delphi survey).

Ninety five percent or more of the respondents of this survey have identified a future level of integration for the 13 CSFs. The number of respondents who have not identified a future level of integration using the proposed SCM framework ranges from 1.7% - 5.0%. This is marginally higher than when questioned on current level of integration (except for CSF 8, as discussed in the previous section). This increase should be expected as it is human nature to be comfortable in assessing the current status rather than a future status of an issue. The increase inadvertently signals that respondents have been somewhat truthful when responding to the question, rather than identifying some future level of integration hypothetically for every CSF. Yet it is important to bear in mind that potentially some respondents may have answered with optimism bias, where they may have identified higher levels of integration in order to shed a better light on their organisation. Moreover, it should be reminded that these validations are based on 60 responses from different tiers of the SC. Due to the target number of responses (refer 4.8.2) not being achieved it is not possible to derive any statistically reliable correlations between the results and categories of respondents.

6.9 Analysis of Section C – Feedback on the proposed SCM framework

Correlation analysis was conducted via SPSS v20 to find if there are significant correlations between responses to section C with section A; for example, if the respondents with most expertise found the SCM framework easier to use than others. However, no significant correlations could be identified, which may suggest that the SCM framework is equally applicable to different types of organisations, to experts and non-experts on SCM, different geographical locations within the UK, etc. It is important to bear in mind that these statistical analyses were based on a limited number of responses (60 responses). Thus, it would be interesting to conduct the e-survey in a few more years, after some economic recovery in the UK, which might allow 179 responses to be collected, which will allow correlations to be identified or nullified, according to G-Power software, with 95% confidence (discussed further in chapter 4).

6.9.1 Ease of use of the proposed SCM framework

The mode and median for the question on the ease of use of the proposed SCM framework is calculated as 2, based on a 5 point Likert scale where 1 = Extremely easy, 3 = Neutral and 5 = Extremely difficult. This suggests that the majority of respondents think that the framework is 'moderately easy' to understand and use. SPSS generates a mean of 2.23, with a standard deviation of 0.767, for the question. Figure 6.23 presents the percentage responses received for the question. The question was compulsory and all 60 respondents have answered the question. It should be highlighted that none of the respondents have claimed that the framework was 'extremely difficult' to understand and use. This is a significant result despite the low number of respondents. However, it should be reminded that non-respondents are more likely to find the framework somewhat difficult to use (refer section 6.4.4).

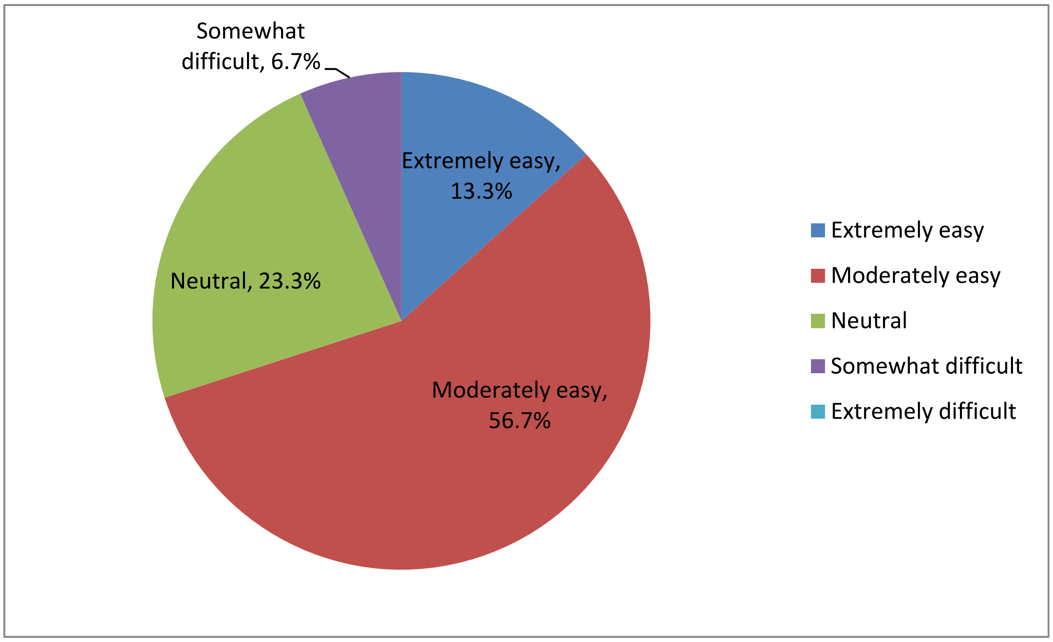

Figure 6.23 – Ease of use of proposed SCM framework

6.9.2 Usefulness of proposed SCM framework when assessing the current level of integration of a supply chain

The question was compulsory and all 60 respondents have answered the question. Out of the 3 categories of responses 91.7% of respondents claim that the framework is very useful or somewhat useful in assessing their SCs (see Fig. 6.24). The rest of the 8.3% of respondents have claimed that the framework is not at all useful in assessing their current level of integration, although a much lesser percentage was actually unable to identify a current level of integration using the framework in Section B discussed previously. A few of these respondents seem to suggest that even though they were able to identify a level of integration for their current status, using the SCM framework, they do not agree that it was useful in assessing their SCs' current level of integration. Moreover, late respondents found the framework more useful in assessing their SCs than the early respondents. Hence it is more likely that the non-respondents would also find the framework more useful in assessing the current level of integration, if the survey was carried out longer for further responses. However, since the analysis of early and late respondents were based on a limited sample size, it is not possible to derive statistically rigorous conclusions.

Since the number of responses claiming that the framework is not at all useful is 5 in number (8.3%) a correlation analysis cannot be done to find out what type of respondents or organisations tend to respond as such. However, an eyeballing of the data reveals that these responses are mostly from respondents who have a good or better level of expertise in SCM in their opinion, but belonging to small construction contractor, client or supplier organisations. This reconfirms the indication revealed in the Delphi survey; that small organisations are not yet very comfortable with the concept SCM.

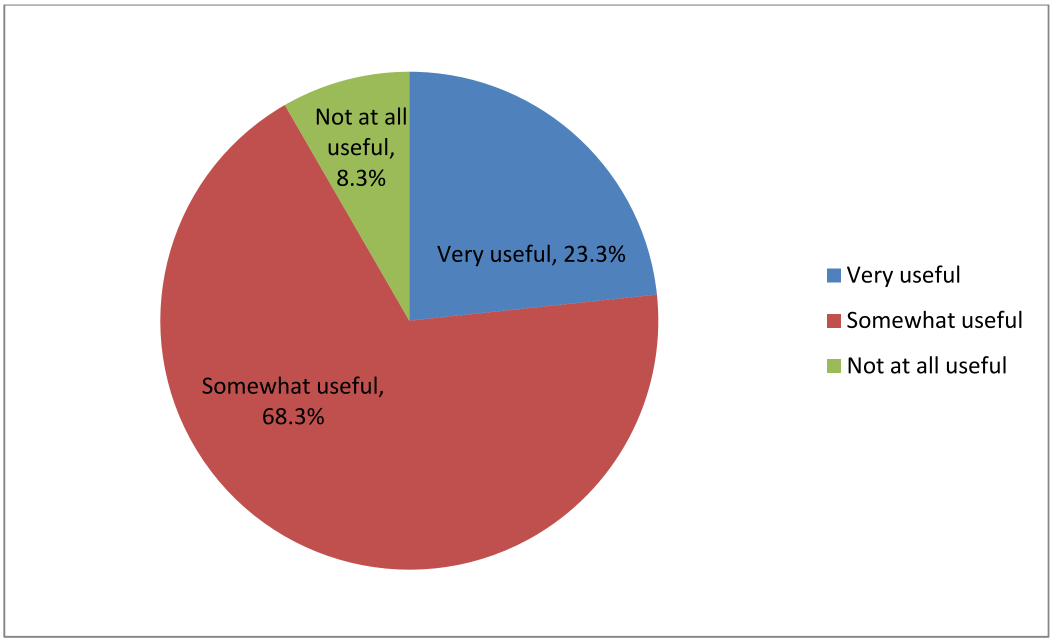

Figure 6.24 – Usefulness of proposed SCM framework in assessing the current level of integration

One of the respondents, out of the five who claimed the SCM framework was 'not at all useful' in assessing their current level of integration, has provided further explanation. He comments that 'the framework does not give us any new insights, and only reflects what we already know and are aiming towards in relation to close working relationships with a selected sub contractor list'. However, the aim of this research, particularly of the Delphi survey which was instrumental in developing the SCM framework, was to collate tacit knowledge of construction experts and build a SCM framework (explicit knowledge) which the whole of the UK construction industry can apply consistently when assessing their SCs.

6.9.3 Usefulness of proposed SCM framework in indicating improvement and progressing to the next level of integration

All 60 respondents have answered this question, even though it is not a compulsory question. 70.0% claim that the proposed SCM framework is very helpful or somewhat useful in indicating improvement and progressing to the next level of integration (refer Fig. 6.25), whilst 21.7% (N=13) have claimed that the framework is not sufficiently descriptive to understand how to move onto the next level, even though the framework allows them to identify the level they strive to be in. SPSS does not produce correlations for 13 responses; hence it is not clear what type of respondents made this claim. Only 2 out of the 13 respondents who claimed that the framework is not sufficiently descriptive have provided further comments. One respondent simply states that the framework only allows assessment, and does not provide insight as to how to implement improvements. The other respondent explains that the framework describes 'states rather than processes', and needs to be complemented with narrative detail on practical steps. Thus it can be concluded that even though 70.0% already find the framework useful in progressing to the next level of integration, the proposed SCM framework has potential to be further improved (via adding details at the operational level, which help identify how to move on to the next level) to help the construction industry improve its SCs. This would be a recommendation for further research.

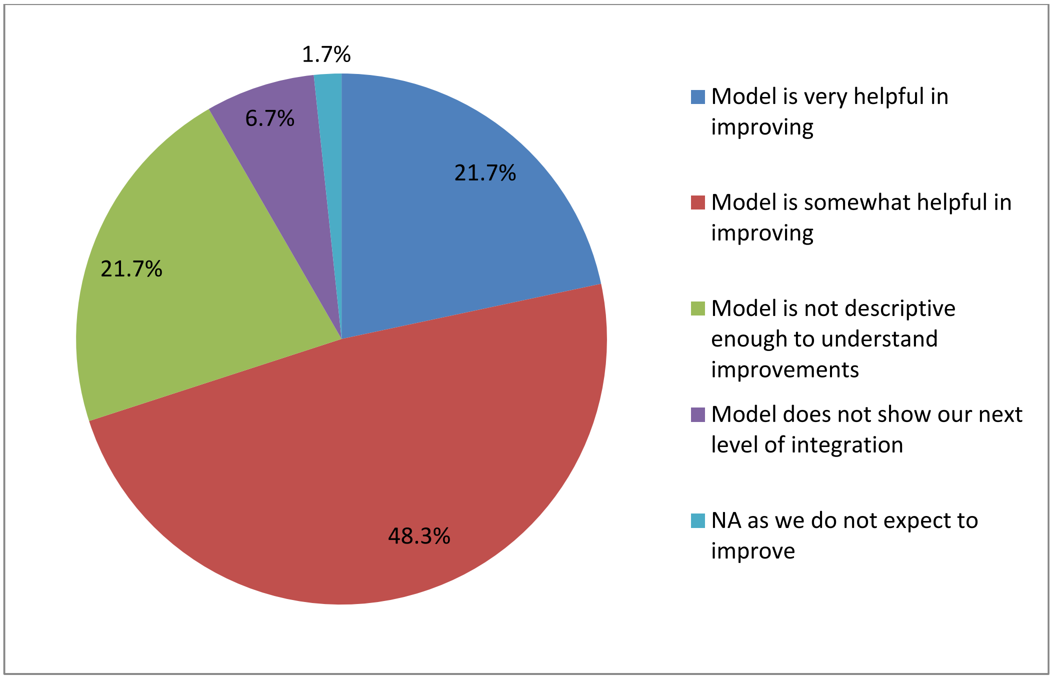

Figure 6.25 – Usefulness of proposed SCM framework in improving SCs

One respondent (1.7%) has claimed that the question is not applicable because his organisation does not intend to further improve. 6.7% of respondents have claimed that the framework does not show the level of integration that they intend to move onto next. Further comments that would help understand the respondents' claims better, have not been provided. It should be noted that most of these respondents are less involved in SCs and belong to small construction organisations. Moreover the number of respondents who have been unable to identify a future level of integration using the SCM framework, in section B, is 5% or less.

6.9.4 Suggested number of levels of integration for proposed SCM framework

59 out of the 60 selected respondents have answered this question, but more than 50% of them have stated that they cannot decide on the best number of levels of integration to be incorporated into an SCM framework for the construction industry. More than a quarter of respondents are in favour of a SCM framework with 4 levels of integration. However, 11.9% think that 3 levels of integration is sufficient, 6.8% think that 5 levels of integration is appropriate and just 1.7% consider a SCM framework with 6 levels of integration. Respondents were given the opportunity to state any other number of levels of integration for this question; however, none have stated any other number of

levels of integration. The percentages presented in Figure 6.26 have been adjusted via SPSS for the missing response.

Thus the number of levels of integration that should be incorporated in an SCM framework for the construction industry is not clear for 52.5% of the respondents (refer Fig. 6.26). Out of the respondents who were clear about the number of levels, 4 levels of integration was most favoured (27.1%). Although generic SCM models mostly presented 4-5 levels of integration, the construction industry seems to favour 3 levels (11.9%) of integration than 5 levels (6.8%). Since 4 levels of integration was the most favoured out of the respondents who were clear about the number of levels in an SCM framework, agreed as most suitable by pilot experts of the Delphi survey, and because literature supports 4 levels of integration it can be established that 4 levels of integration is appropriate for this framework.

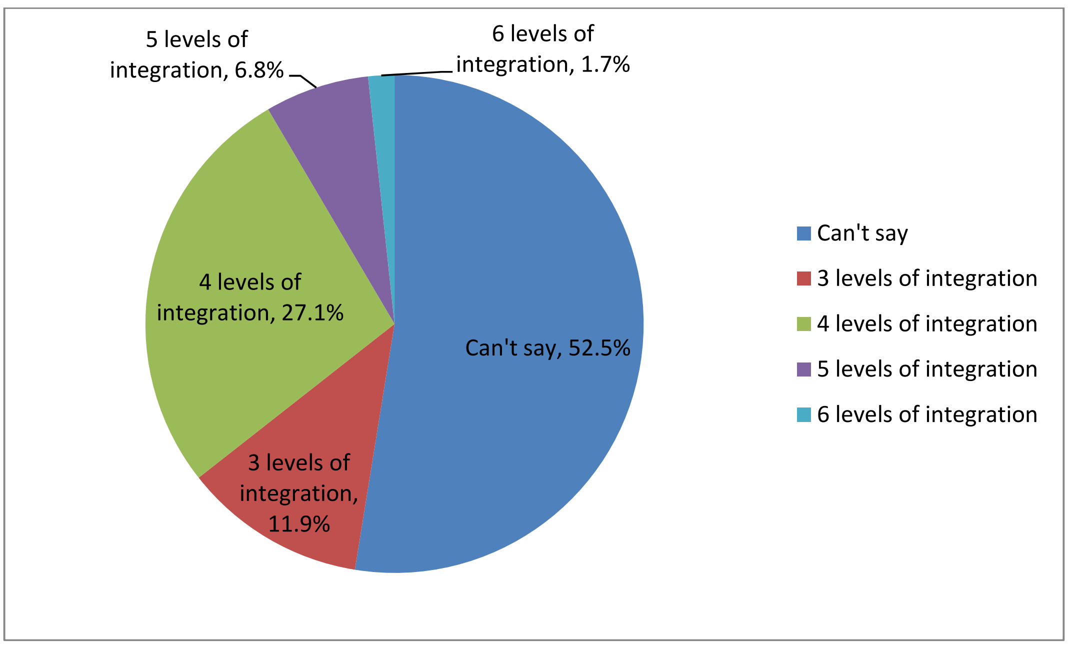

Figure 6.26 – Suggested number of levels of integration for proposed SCM framework

6.10 Conclusion of propositions

Correlation analysis using SPSS v20 was conducted for all questions, but no significant correlations were identified apart from the obvious relationships such as turnover of an organisation and the level of involvement of SCs or level of involvement in SCs and expertise in SCM. Yet these correlations were established based on the whole sample and not per category of respondent due to lack of responses to conduct ANOVA F tests. Hence propositions can only be concluded in general for the entire construction industry, and not per sub-sector or category of respondents.

6.10.1 Proposition 1: Construction professionals find it easy to use the framework.

SPSS generated a mean of 2.23, with a standard deviation of 0.767, for the relevant question in the questionnaire. Hence it can be concluded that the average response is that the framework is slightly more than 'moderately easy' to use. The mode, that is the most popular answer confirms that the framework is 'moderately easy' to use. There was only 6.7% who find the framework 'somewhat difficult' to use, and 0% found the framework 'extremely difficult to use (refer Fig. 6.23). No significant correlations could be identified between these responses and type of organisations, expertise of respondents, etc. Hence the null hypothesis (construction professionals do not find the SCM framework easy to use) cannot be rejected. Therefore it can be concluded that most construction professionals find the proposed SCM framework easy to use. However, it should be noted that these results are based on 60 responses, and that non-respondents were more likely to find the framework difficult to use than early respondents (refer section 6.4.4).

6.10.2 Proposition 2: The number of levels of integration in the framework is suitable for the construction industry.

The 4 levels of integration were determined for the framework based on previous literature and pilot experts of the Delphi survey. The respondents of the e-survey were also given an opportunity to comment on the number of levels of integration on the SCM framework. However, 52.5% of the respondents stated that they cannot say what the appropriate number of levels of integration is for the construction industry (refer Fig. 6.26). More than a quarter (27.1%) agreed on 4 levels of integration, and lower percentages for other number of levels of integration. Thus based on the respondents who were certain about the levels of integration, 4 levels is considered most suitable for a SCM framework of the construction industry.

6.10.3 Proposition 3: Construction professionals find the framework useful in gauging the level of supply chain integration in a project.

Except 8.3%, all other (91.7%) respondents found the SCM framework useful in gauging the level of integration of their organisation's SCs (refer Fig. 6.24). However the actual percentage of respondents who were unable to identify a current level of integration (based on 'do not know' responses in section B) using the framework was 1.7% or less (except for one outlying CSF discussed in section 6.6.8). Moreover, it should be noted that non-respondents are more likely to consider the framework more useful in assessing their current level of integration (refer section 6.4.4). Hence it can be concluded that in general most construction professionals find the SCM framework useful in assessing their organisations' SCs.

6.10.4 Proposition 4: The framework indicates how to improve and move on to the next stage of supply chain integration.

Although 95% or more respondents were able to identify a future level of integration based on the proposed SCM framework in section B of the questionnaire, 6.7% have claimed that their future level of integration is not included in the framework when responding to section C of the questionnaire. With regard to the usefulness of the framework in improving SCs, 70% of respondents agreed that the SCM framework is helpful in improving their SCs and to move on to the next level of integration (refer Fig. 6.25). However, a significant proportion (21.7%) has stated that they cannot understand improvements they need to make with the help of the framework. Hence it can be concluded that the majority of construction professionals find the SCM framework useful in gaining an insight with regard to future levels of integration to be achieved, although a significant minority does not find it sufficiently descriptive in explaining how to improve. Hence as identified in section 6.9.3, further research needs to be carried out to further improve the framework.

6.10.5 Proposition 5: All sub-sectors of the construction industry can relate to the SCM framework in general.

The percentage of respondents who were able to assess their SCs was 95% or more for questions, current level of integration and future level of integration (refer figures 6.21 and 6.22). Thus it appears that most construction professionals from all categories client, consultant, contractor and supplier are able to assess their SCs using the proposed SCM framework. The survey indicated that construction professionals from small organisations may struggle to understand the framework. There was no significant correlation between the types of responses and types of organisations according to analysis via SPSS. G-Power software suggested that a total of 179 responses will be needed to identify correlations, via ANOVA F tests, among 4 categories of SC members, at 80% power and 95% confidence level. Hence this proposition cannot be conclusively rejected as being correct due to the limit of 60 responses having being analysed. Yet due to 95% or more of all construction professionals being able to use the framework and identify a level of integration for all 13 CSFs suggest that the framework can be related to by most professionals from all sub-sectors.

6.11 Summary

The chapter described the development of the questionnaire, database and the execution of the questionnaire survey in the UK. It was revealed that response rates for questionnaire surveys are low in the construction industry regarding the subject SCM. Yet this research conducted the e-survey to substantiate construction SCM research with quantitative results, as done in the manufacturing industries. Sixty responses were sufficient to test the framework, as required for theory development; but were not sufficient to identify correlations among the four categories and types of responses. The survey was able to identify the current and anticipated future levels of integration for construction organisations, in addition to testing the framework.

With regard to testing of the framework, in summary, the proposed SCM framework is generally useful in assessing the integration of construction SCs and is moderately easy to use for most construction professionals in the UK. The majority of the construction professionals find that the SCM framework is useful in prescribing improvements for the future. However, the SCM framework has further room for expansion in its prescriptions for improvement in the future, as a significant minority of construction professionals indicated in terms of details included at the operational level. However, this is beyond the scope of this research, which was to develop a SCM framework applicable at the strategic level. The inclusion of further details on prescribing improvements for the future could be done via case studies, as part of further research, which could also be a mechanism to verify the level of applicability to different categories of the construction industry; namely clients, consultants, contractors and suppliers. As at present, due to the lack of SCM experts in the construction industry, it is difficult to validate the proposed SCM framework for the different categories.

Chapter Seven

Discussion of Findings

Chapter 7 – Discussion of findings

7.1 Scope of chapter

The main finding of this research is the SCM framework that was developed to help the construction industry assess and improve their SCs. This framework is included in appendix 16. The CSFs for inclusion in the framework were examined in chapter 3, the production of the framework via the Delphi method was presented in chapter 5, and the testing of the framework was discussed in chapter 6. This chapter summarises and reflects on the development of the framework, discusses its importance in light of previous literature and its applications to the construction industry.

7.2 Reflecting on the development of the framework

It was established in chapter 4 that to develop a theory a two-staged process of theory building and theory testing has to be adhered to. The theory building process should be inductive (Farquhar, 2012; Vaus, 2001). The need for induction was apparent for the research, due to lack of literature and the nature of the task that was at hand at the time: to create a SCM framework for the construction industry. Hence the Delphi method, a technique which allows the compilation of thoughts from experts via several iterations, was deployed to produce the framework. This was a qualitative exercise. Due to the requirement to select well vetted experts (since expertise is crucial for a Delphi survey as claimed by Chan et al., 2001; Dalkey, 1969) and maintain a good relationship to promote higher response rates, the Delphi survey was conducted within the Northern Irish construction industry. The thirteen CSFs compiled based on previous literature was explored among the Delphi experts, and thereafter based on scores achieved, were all included in the framework. The experts did not add any further substantial CSFs. Moreover, factor analysis confirmed the inclusion of all 13 CSFs. The framework included four levels of integration.

Level 1- Minimal integration: Departments/Sections within the assessed construction organisation are not integrated/ collaborative. This should be considered the worst case scenario that has been observed within the construction industry.

Level 2- Internal integration: Departments/Sections within the assessed construction organisation are internally integrated, but not integrated with any external organisations.

Level 3- Some external collaboration: In addition to internal organisational integration, there is some collaboration with few external organisations.

Level 4- Extensive external collaboration: There is evidence of extensive internal and external organisational collaboration. This would be the best case scenario that can practically be expected from construction supply chains.

Thereafter, to test the framework a questionnaire survey was conducted throughout the UK. This was a deductive and quantitative exercise. The questionnaire for the e-survey requested general information from respondents, and then asked to assess their SCs based on the developed framework before providing feedback on the framework. Hence in addition to testing the framework, another result was obtained; that is the current and future levels of integration of the construction SCs. The e-survey received 68 responses, out of which 60 responses were selected for analysis. This possibly is one of the first quantitative surveys that have been conducted, with a SCM focus, among individuals in the construction industry. However, this number of responses was not sufficient to generate correlations with regard to the applicability of the framework among different sub-sectors of the construction industry such as clients, consultants, contractors, etc. However the results generated indicated that the framework is applicable to most construction professionals in all sectors. For example, 95% or more respondents were able to identify a current and future level of integration for their construction organisation based on the SCM framework (refer chapter 6).

This framework is a unique finding for the UK construction industry due to the lack of empirically tested SCM frameworks available, and its ability to be applied at the organisational level in a project-oriented industry (refer section 5.8). The organisational focus is important because SCM has a long-term outlook, and should not be viewed simply with a short-term project perspective (unless maximising benefits of the concept is not important). Hence this research contributes a SCM framework that is empirically tested, easy to use and useful in assessing and improving SCs for construction organisations.

7.3 *Discussion of the framework*

The 13 CSFs included in the framework are discussed below in their order of importance, as identified from the Delphi survey. The comparisons between current and future levels of integration are based on Fig. 6.21 and Fig. 6.22 from chapter 6.

7.3.1 CSF 1 – Positive attitude and approach to working relationships

This CSF achieved the highest mean for its importance to SCM. The mean was 4.3548, which produces a weighted average of 9.28% (refer section 5.5.4). The framework describes organisations at Level 1 for this CSF as there will not be much interaction between SC members and no facilitation of working relationships. However, as an organisation starts appreciating the need for collaboration, relationships will begin to develop. At Level 4 relationships will be established, with interdependability among SC members and all being involved throughout a project. Despite claims of attitudinal problems in the construction industry by Briscoe et al. (2001) and Fearne and Fowler (2006) it was revealed that 63.3% of organisations identify them to be in Level 3 or 4 with regard to CSF 1. They also claim that 76.7% of organisations will be in Level 3 and 4 in 3-5 years.

7.3.2 CSF 2 – Support and commitment of leaders/ senior management of all supply chain member organisations towards integrated supply chains

This CSF achieved a mean of 4.2258, which computed a 9.00% weighted average based on the means of all 13CSFs (refer Table 5.10). According to Egan (2002), Brewer et al. (2005) and Yeung et al. (2009) integration cannot be promoted without the support and the commitment of senior managers or leaders. Hence this CSF was included in the framework, and the Delphi survey revealed that it's the second most important CSF to the construction industry in promoting SCM ethos. The framework describes that organisations at Level 1 would be the organisations where their senior management is not aware of the benefits of SCM, hence not motivated to promote it; whilst at Level 4, the expectation is that there will be documentation and procedures endorsed by the senior management to support collaboration and possibly collaboration embedded in culture. When assessing the SCs based on this description, 63.3% of construction organisations identified themselves as in Level 3 or 4 for this CSF. They also claimed that 78.3% will be in Level 3 or 4 in 3-5 years.

7.3.3 CSF 3 – Level of trust between supply chain members

This was the third most important factor for the Delphi experts. It achieved a 4.1935 score and a weighted average of 8.93% (refer Table 5.10). Yeung et al. (2009) has recognised trust, both internally and externally, as very important to relationships in the construction industry. Egan (1998) and Egan (2002) implied the same. Forms of contracts such as the NEC promote trust in the construction industry, and according to the RICS (2012) high value projects are increasingly adopting this. The framework identifies that trust will be very limited at Level 1, possibly due to poor relationships, communication and lack of understanding of SCM. These companies will probably be operating within silos, practicing blame culture, etc. whilst at Level 4 trust would exist among SC members due to frequent communication, team building events, open discussions, long term partnering, open book accounting, etc. It was also recognised that prompt payment to SC members should be made in order to demonstrate trust.

Based on the above description the questionnaire survey revealed that most organisations (66.7%) recognise themselves as belonging to Level 3 currently. However, only 3.3% placed themselves in Level 4. This is the lowest percentage at Level 4 recognised for current level of integration amongst all 13 CSFs. This result shares the claims in literature that trust is lacking in the construction industry. However, in 3-5 years 26.7% of organisations predict they will belong to Level 4. This is the highest improvement recorded for Level 4 out of all 13 CSFs. Hence it appears that the industry recognises this CSF as a measure which needs dramatic improvement. Yet it should be noted that the organisations who are currently belonging to lower levels of integration demonstrate minimal interest in improving to higher levels of integration. Hence the construction industry may, in future, have two subdivisions who are embracing trust within work practices (high level of trust) and who are not very keen in embracing a culture of trust (low level of trust), with no organisations at medium levels of trust.

7.3.4 CSF 4 – Extent of communication between supply chain members

CSF 4 achieved a score of 3.9677, which resulted in a weighted average of 8.45%. This is the fourth most important CSF according to the Delphi survey. Communication was also identified as critical to SCM in non-construction specific and construction specific literature (refer chapter 3). The developed framework describes CSF 4 at

Level 1 as having very limited communication, as part of contractual requirements. At Level 4, CSF 4 is described as having good communication with all SC member organisations from early stages of projects. Communication at this stage is frequent, efficient, effective, constructive and extensive. The formal communication system will be accessible by all SC members.

Based on the framework's descriptions 66.6% of organisations are currently belonging to Level 3 or 4. Similar to CSF 3, CSF 4 only records a marginal improvement (to 68.3% of organisations) at higher levels of integration in 3-5 years. This is due to organisations currently in Level 1 or 2 not striving to achieve higher levels of integration in 3-5 years. However, there are significant shifts from organisations currently belonging to Level 3, to Level 4, in 3-5 years. Therefore, similar to CSF 3, the industry may experience two subdivisions of organisations where one embraces good communication at the most sophisticated level, and remaining organisations who limit communication to contractual commitments when dealing with SC members. Since there is a link between communication and trust (Delphi experts recognised communication as fundamental to trust), CSF 3 and 4 behaving similarly can be comprehended.

7.3.5 CSF 5 – Degree of collaboration, between supply chain members, when making key decisions

The fifth most important CSF achieved a mean of 3.7097, which resulted in a weighted average of 7.90% (refer Table 5.10). Lockamy and McCormack (2004) and PRTM (2002) identify real-time collaboration via IT infrastructure at the highest level of integration, where all SC members can be included in a virtual organisation when making decisions. With the promotion of software such as BIM in recent years within the construction industry, these approaches adopted in manufacturing and IT industries so far, can be embraced by the construction industries.

Since the Delphi survey was conducted in 2009/2010, none of the respondents identified BIM for this CSF (BIM became popular in the UK construction industry afterwards). They instead recognised proactive collaboration occurring at the highest level via IT based communication systems and regular meetings. BIM, or any other relevant databases, would be the IT based communication system they recognised. The questionnaire survey revealed that most organisations currently belonging to Level 2 and 3 will move to higher levels of integration in 3-5 years, where 70% of organisations will belong to Levels 3 and 4 in future. In fact, in future there will be more organisations belonging to Level 4 (36.7%) than any other level, whilst all other CSFs indicate that even in 3-5 years most organisations will belong to Level 3. Hence the industry now anticipates momentous improvement with regard to CSF 5, which should improve integration of SCs significantly.

7.3.6 CSF 6 – Availability of a vision, mission, strategy, policy and procedures for management of supply chains

This CSF achieved a mean of 3.4839 and a weighted average of 7.42% (refer Table 5.10). Previous literature on SCM does not emphasise this criterion very much. However, theories on organisational management have recognised the importance of a vision, etc. to an organisation. Hence for the potential creation of a virtual organisation, as described in the previous section (CSF 5) it is essential that CSF 6 is included in the framework. CSF 6 achieved the 6th place with regard to its importance to SCM during the Delphi survey.

The descriptions for CSF 6 in the framework progress from non-existence to formal and detailed documentation in place, encompassing the entire SC at the highest level. It recognises that the entire SC should contribute to and support the vision, mission, etc. at Level 4 (Refer Appendix 16). Based on these descriptions, 41.7% of the respondents to the questionnaire survey recognised that they currently belong to Level 3 or 4. This percentage is quite low when compared with CSFs 1 – 5. Then again, CSF 6 is less important than CSFs 1 – 5. According to the questionnaire survey 63.4% of organisations will be in levels 3 or 4 in 3-5 years.

7.3.7 CSF 7 – Availability and use of IT for collaboration between supply chain members

Although previous literature identifies IT as crucial to communication, real-time collaboration, etc. (refer section 3.5.3) the Delphi survey identified CSF 7 as the 7th important factor. The mean achieved was 3.4516, which resulted in a weighted average of 7.35% (refer Table 5.10). Delphi experts described Level 1 of the framework as ‘No or inadequate IT systems in place. Usage of IT will be limited to emails/fax. SC members have limited IT skills', and Level 4 as 'There will be extensive IT collaboration, where IT training is provided and access allowed for all SC members. The IT strategy will be agreed across the SC and IT usage for collaboration will be made compulsory. All SC members will have good IT skills and compatible IT systems'. Based on the framework, the respondents to the questionnaire recognised that there are only 38.3% of organisations at Level 3 or 4 at present. This percentage is quite low in comparison to other criteria. However, 75% of organisations expect to belong to Level 3 or 4 in future, which implies that the industry now recognises its importance. Yet the improvement expected at Level 4 is not very high. This may be due to resource constraints in a project oriented industry, where the payback period of investment in IT is not very high when an organisation is constantly dealing with short-term projects. Further research needs to be conducted with regard to this issue to establish the break-even point for investment in IT for organisations that constantly deal with short-term projects.

7.3.8 CSF 8 – Existence of a protocol for conflict resolution among supply chain members

CSF 8 achieved a mean of 3.3871 and a weighted average of 7.22% in the Delphi survey. Richbell (2008) claims that the construction industry is prone to conflict. Hence as discussed in chapter 3, it is important that SC members have access to a protocol for conflict resolution. The framework recognises that at Level 1 there will be no such protocols, apart from any contract mechanisms, whilst at Level 4 there will be formal protocols available for the entire SC, where all SC members were involved in developing the protocol. It also explains that regular meetings should be held to address issues and avoid conflict. Based on these descriptions, only 35% organisations currently belong to Level 3 and 4 of the framework whilst 65% predict they will belong to these higher levels in 3-5 years. That would be a significant shift, which suggests that the respondents recognise its importance.

7.3.9 CSF 9 – Existence of a system to measure performance of supply chain members

CSF 9 achieved a score of 3.3548 and a weighted average of 7.15% based on the Delphi survey (refer table 5.10). Non-construction specific models such as of McLaren (2006) and construction specific research such as of Yeung et al. (2009) recognise the importance of performance measurement and improvement. The framework describes progression of the CSF from no system to measure performance to, at the highest level, 'There are systems in place for collaborative performance measurement. These systems are comprehensive, consistent, aligned across the SC, contractual and formal. SC members are involved in the development of this system, understand the process of measurement and are proactively encouraged to use performance measurement.' Based on this description 50% of organisations recognised themselves as belonging to Level 3 or 4 currently, whilst 70% recognised they will be in these higher levels of integration in 3-5 years.

7.3.10 CSF 10– Procurement methods used to procure projects

CSF 10 achieved a mean of 3.300 and a weighted average of 7.03% for the Delphi survey (refer Table 5.10). As discussed in chapters 2 and 3, procurement has an effect on the potential to collaborate. The framework describes Level 1 for CSF 10 as 'Traditional procurement methods are used, and is driven through price alone. Procurement methods are chosen in an adhoc manner and SCM is not mentioned or encouraged.', and Level 4 as 'Procurement methods promote partnering, long-term collaboration, performance related payments and open-book accounting. The SC demonstrates good understanding of all types of procurement methods. The procurement strategy is developed by all SC members to suit the project, and there is commitment to key SC members for long-term partnerships.' Based on the framework, 61.7% of organisations identify themselves belonging to Level 3 or 4 currently, whilst 80% expect to achieve these levels in 3-5 years. Thus the industry seems to prefer collaborative forms of procurement to traditional forms of procurement, despite the potential inapplicability of such procurement methods to some projects. However, it should be noted that most responses for this type of surveys are received from SCM enthusiastic organisations.

7.3.11 CSF 11 –Length of project duration or Continuity of work to sustain the supply chain

CSF 11 achieved a mean of 3.2903 and a weighted average of 7.01% (refer Table 5.10). Fearne and Fowler (2006) recognise that short project durations create problems for the construction industry, such as attitudinal issues. Moreover Brewer et al. (2007) state that investment in resources, such as IT, become questionable where there are short payback periods involved. Hence continuity of works is of paramount importance to the construction industry. The framework recognises that at the highest level of integration there should be a formal contractual commitment to continuity of work and long-term relationships with SC members. Furthermore, SC members are well-integrated even for a single or short-term project and are actively encouraged to bring opportunities/projects to collaborate in future.

However, as discussed earlier, more research is required to establish the level of investment and integration which is financially feasible when involved in short-term projects. It should be noted here that there were two approaches or schools of thought with regard to CSF 11, among the Delphi experts; namely,

1. Continuity of works leads to improved integration.
2. Collaborative ethos leads to improved integration even for short-term projects (hence by implication, continuity of works is not essential for well-integrated SCs, although there would be implications of a shorter payback period to make a return on the investment to collaborate).

Both underlying arguments are correct to some extent within the construction context. Further research is required to establish if investment to integrate is financially viable for organisations constantly dealing with short-term projects. However, the validity of such research can be contested very soon in the future, due to potential lower costs of investment. For example, costs of software could be much cheaper in the future.

Based on the descriptions of the framework, 55.0% of organisations recognised themselves as belonging to Level 3 or 4 currently, and 71.6% of organisations as belonging to these higher levels of integration in 3-5 years. Thus, despite above discussed barriers to integration due to belonging to an essentially project-oriented industry, the construction organisations strive for higher levels with regard to CSF 11.

7.3.12 CSF 12 – Promoting engagement of all supply chain members at the client briefing stage

CSF 12 achieved a mean of 3.2258 and a weighted average of 6.87% (refer table 5.10). Most SCM models incorporate linkages with their customers (refer chapter 3). This is particularly important in the construction industry where clients' needs have to be clearly understood to deliver a bespoke and complex product, as implied by Love et al. (2004) and Egan (2002). Thus the developed framework progresses from minimal and informal briefing at Level 1, to all SC members being involved in developing the client brief at Level 4. Based on these descriptions, 51.6% of organisations belong to Level 3 and 4 at present and 71.7% of organisations aim to be at these higher levels in 3-5 years.

7.3.13 CSF 13 – Existence of a strategy for training and development of supply chain members

CSF 13 achieved a mean of 3.000 and a weighted average of 6.39% (refer table 5.10). Training and development is recognised as important for improved collaboration as discussed in chapter 3. The developed framework describes CSF 13 at Level 1 as having no strategy to develop people internally or externally, whilst at Level 4 as having a strategy for training and development of SC members and compulsory adherence to strategy. It further explains that there should be regular and accountable training provided to all SC members, and that these programmes should be designed and implemented with the involvement of the SC.

This CSF currently has more organisations belonging to Level 1 than the higher levels of integration, which is quite different to other CSFs (refer Figure 6.20). CSF 13 is the least important factor out of the 13 CSFs and it demonstrates the lowest number of organisations in higher levels of integration (Levels 2 - 4). The current percentage (33.3%) of organisations in higher levels will, however, increase to 65% in 3-5 years. Yet the number of organisations at Level 4 with regard to this CSF will be the lowest out of the 13 CSFs in 3-5 years.

7.4 Summary of chapter

This chapter summarised and discussed the information generated with regard to the developed SCM framework from chapters 3, 5 and 6. It explains the importance of each CSF based on literature and the Delphi survey, discussing any similarities or deviations from previous literature; such as lack of trust in the construction industry or attitudinal problems. It also describes the progression of each CSF in the developed framework, based upon which the current and future levels of integration of the construction industry was assessed. The comparison and discussion of current and future levels of integration for each CSF, and among other CSFs, provide some insight to the current status and the future status of the construction industry. For example, it was revealed that there could be two subdivisions in the construction industry in 3-5 years, where organisations will be at two extreme ends with regard to trust and communication; where some organisations have fully embraced a culture of trust and a sophisticated level of communication, whilst the other remaining organisations will be at the other end of the spectrum and will not be open to improving levels of trust or communication apart from any contractual commitments. The chapter, therefore, provides the construction industry with an overview of SCs at present, a glimpse into the future, whilst discussing a framework which allows the individual construction organisations to assess and improve their SCs.

Chapter Eight

Conclusions and Recommendations

Chapter 8 – Conclusions and Recommendations

8.1 Scope of chapter

This chapter concludes all objectives derived from the aim of this research, and lists the key findings and contribution to knowledge created from the research. It also identifies limitations of the research, and provides recommendations to the construction industry, and for further research.

8.2 Conclusion of objectives

The main aim of this research was to develop a framework which allows assessing construction supply chains, and thereby encouraging improvements in SCM practices. The following objectives, derived from the aim of research, are concluded as follows.

Objective 1: To systematically comprehend the application of principles of SCM in the construction industry.

Based on literature presented in chapter 2 it can be concluded that SCM is about establishing networks which will allow a smooth flow of information, which will in turn enable supply chain partners to make informed decisions. Collaborative decisions will allow organisations to have better coordination of SC members, improved stock availability, synchronised flow of operations, responsiveness, reduced operational costs, competitive advantage and increased customer satisfaction (refer section 2.4.3). The level of integration of a supply chain depends on quality, quantity and timeliness of information. Information could help decision making at the strategic or operational level of supply chains. In this sense, the concept is equally applicable in the construction industry as much as in other industries, despite arguments from authors such as Fernie and Thorpe (2007) who claim that SCM is not applicable in the construction industry due to its nature of project orientation. However, the construction industry does have challenges to overcome such as attitudinal problems, issues of trust and conflict and lack of continuity of work unlike in manufacturing industries. These arguments reinforce the need to develop a SCM framework applicable to the construction industry, as aimed in this research, due to the industry's uniqueness.

Objective 2: To critically analyse SCM models available in literature for the construction industry (if available) and non-construction industries.

Various models on SCM are available in literature which has been produced for different industries such as IT, manufacturing and construction. However, the number of models relevant for the construction industry is limited. And also they are not tailored towards construction organisations, but instead are project specific. Furthermore the data collection process for these models has been qualitative. This limits their ability to be applied across the industry. Moreover, unlike many non-construction related models that include levels of integration which demonstrate how an organisation progresses from stage to stage with regard to their SCs, the construction related models do not encompass different stages of integration. Thus a knowledge gap was identified where there was a need to develop a SCM model with stages of integration for the construction industry, as such models allow users to understand how an organisation can improve over time and identify at which stage they are currently at. Most generic SCM models that included levels of integration for SCs had 4-5 levels of integration. These SCM models offered descriptive headings for the different levels of integration. Hence the following 4 headings were adapted for the developed framework based on various models: Level 1- Minimal integration; Level 2- Internal integration; Level 3- Some external integration; Level 4 - Extensive external integration. The research reported in this thesis fills the knowledge gap identified above.

Objective 3: To develop a set of critical success factors (CSFs) that lead to SC integration in the construction industry.

A set of 13 CSFs was developed based on various literature on SCM and related concepts; namely 1) Positive attitude and approach to working relationships, 2) Level of trust between SC members, 3) Availability and use of IT for collaboration between SC members, 4) Promoting engagement of all SC members at the client briefing stage, 5) Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs, 6) Procurement methods used to procure projects, 7) Length of project duration or Continuity of work to sustain the SC, 8) Extent of communication between SC members, 9) Existence of a system to measure performance of SC members (i.e.KPIs), 10) Existence of a strategy for training and development of SC members, 11) Existence of a protocol for conflict resolution among

SC members, 12) Degree of collaboration, between SC members, when making key decisions, and 13) Availability of a vision, mission, strategy, policy and procedures for management of SC.

These CSFs were originated from non-construction models encompassing levels of integration such as PRTM (2002), Hoffman and Reiner (2006), McLaren (2006) and Stevens (1989). Then further CSFs were added based on construction related literature such as Egan (2002), RICS (2010) and Yeung et al. (2009). Thereafter, the 13 CSFs were validated in Round 1 of the Delphi survey in 2010. The scores for prioritisation and the process of convergence of the scores among the Delphi panellists are explained in Chapter 5. The Delphi experts were given an opportunity to suggest additional CSFs to the list generated via literature, and none of the experts were able to suggest any CSFs that were not already encompassed within the set of 13 CSFs. Hence it can be concluded that the set of CSFs is robust and valid to construction SCs.

Objective 4: To develop a framework that allows assessing and improving integration of construction SCs.

The Delphi method was deployed within the Northern Irish construction industry to develop a framework which allows assessing and improving of construction SCs. The aforementioned 13 CSFs were elaborated with descriptions across 4 levels of integration by the Delphi panellists. Their responses were converged through a lengthy process of data reduction, whilst making every attempt to retain the richness of the breadth and depth of responses. The analysis of this data is included in Appendices 14-16. The background of the Delphi method, selection of Delphi experts, the various Delphi iterations conducted and analysis of data is explained in chapters 4 and 5. The SCM framework developed through this process is included in Appendix 16.

Objective 5: To test the framework with regard to its ability to assess and improve integration of construction SCs.

A UK wide questionnaire survey was conducted among construction clients, consultants, contractors, subcontractors, and material and plant suppliers to validate the developed SCM framework. The 68 respondents who completed the questionnaire used the SCM framework to assess their SCs in its current status, and then gauged their organisation's anticipated level of integration in 3-5 years. Out of the 68 responses, 60 responses were selected for analysis based on the scope of research. None of the respondents found the framework 'extremely difficult' to use. Moreover, 91.7% of respondents claim that the framework is very useful or somewhat useful in assessing their SCs. Furthermore, 95% or more respondents were able to assess their SCs via application of the framework. Also, 70.0% claim that the developed SCM framework is very helpful or somewhat useful in indicating improvement and progressing to the next level of integration. Further information and statistics are discussed in chapter 7 of this thesis. The assessments of the current and future level of integration of respondents are discussed under the next objective.

Objective 6: To evaluate the current and future levels of integration of construction SCs, conclude and make recommendations to the construction industry and academia with regard to integration of SCs in the UK.

The current level of integration for most organisations is Level 2 or 3, based on the developed SCM framework. The percentage of organisations belonging to Level 4 currently is 20% or under for all of the 13 CSFs. The CSF with the highest percentage of organisations for level 4 currently is CSF 1: 'Positive attitude and approach to working relationships' according to the respondents of the esurvey. This is in contrast to previous literature (Briscoe et al., 2001; Fearne and Fowler, 2006) claiming adverse relationships in the construction industry. The CSF with the lowest percentage of organisations (3.3%) at Level 4 for current level of integration is CSF 11: Minimum length of project duration or Continuity of work to sustain the SC. Further research is required with regard to the break-even point for investment in integrated SCs within a short-term project environment. Further analysis of the current level of integration of SCs can be obtained from chapter 7.

Although many organisations expect to improve their level of integration in 3-5 years, the modes for all CSFs, except CSF 5, remain Level 3. However, the percentage of organisations at Level 4 has increased from under 20% at the current level of integration to under 37% of organisations. The CSFs that will achieve the highest number of organisations (36.7%) in Level 4 in 3-5 years are CSF 5 (Degree of collaboration, between SC members, when making key decisions) and CSF 1 (Positive attitude and approach to working relationships). CSF 1 obtained the highest percentage of organisations (20%) for Level 4 for the assessment on current level of integration. Hence this is an improvement of 16.7%. The improvement for CSF 5 will be 20% from its current level of integration. With the implementation of systems such as BIM, it would not be difficult to achieve such improvement in 3-5 years.

The CSF that will have the lowest number of organisations (13.3%) in Level 4, in 3-5 years, is CSF 13 (Existence of a strategy for training and development of SC members). However, it should be noted that this is an improvement as CSF 13 was the only CSF which received a mode of Level 1 when assessed on current level of integration. The CSFs that will have the lowest number of organisations (1.7%) remaining in the lowest level of integration (Level 1), in 3-5 years, would be CSFs 1 (Positive attitude and approach to working relationships), 3 (Level of trust between SC members) and 4 (Extent of communication between SC member). Hence it appears that a significant culture change could be expected in the future. These are further elaborated in chapter 7.

As advocated in government reports such as Egan (1998) and Wolstenholme et al. (2009), SCM can bring significant benefits to the construction industry, when practiced in the long run. The set of CSFs included in the SCM framework is comprehensive and robust. Most construction professionals in the UK find the developed SCM framework easy to use, helpful in assessing their current level of integration and understanding future improvements required. Hence the use of the developed SCM framework can be recommended to the UK construction industry, as it is a comprehensive and robust framework which has been tested via empirical data in the UK. However, small construction organisations may struggle to apply the framework to their organisations by themselves. Furthermore, the applicability of SCM when organisations are constantly dealing with short-term projects needs to be researched further, due to short payback periods becoming a barrier when investing to promote integration of SCs.

8.3 Contributions to knowledge and key findings of this research

This research contributes significantly to the body of knowledge on SCM, of the construction industry, in the following ways.

- The research reviewed SCM models from non-construction industries and analysed their inapplicability to the construction industry. The literature review also established the need for a SCM framework for the construction industry which allows assessing SCs, and thereby encouraging improvements to construction supply chains (refer chapter 3).
- The research compiled a set of factors which are critical to the success of integration of construction SCs, and computed a set of scores for each of these 13 CSFs. Hence it is clear to construction organisations, which factors are most critical to SCs, out of the 13 CSFs. This list would be the first of its kind that is made available to the UK construction industry, which has been tested empirically (refer section 5.5.4).
- The research developed an 'easy to use' SCM framework based on the 13 CSFs and 4 levels of integration, which allows construction professionals to assess their SCs and understand improvements required for the future, which fills a knowledge gap in SCM research in the construction industry (refer section 6.10 and Appendix 16).
- The developed SCM framework is applicable at organisational level, based on experiences at project level. This is a significant breakthrough in SCM research in the construction industry, where previous research only represents a project perspective (refer sections 5.8.1 and 7.2).
- This possibly is the first quantitative survey that has been conducted, with a SCM focus, among individuals in the construction industry (Ebrahimy et al., 2011 claims that all previous SCM research has been qualitative in the construction industry).
- Many construction organisations currently belong to Level 2 and 3 based on their level of integration of construction SCs, and to Level 3 and 4 based on their future level of integration (refer 6.7 and 6.8).
- A very low number of organisations currently belong to the highest level of integration with regard to the level of trust. This finding complies with previous literature. However, the industry hopes to improve significantly in this aspect in 3-5 years (refer 6.6.3).
- There could be two varieties of construction organisations in the future; one group which is highly integrated, and the remaining group which is hardly integrated with regard to the level of trust and communication. This is due to

the trend where construction organisations who are currently in Level 2 or 3 showing inclination to improve further, whilst organisations who are currently at Level 1 not demonstrating any interest in improving further (refer sections 7.3.3 and 7.3.4).

- Most construction organisations expect to further integrate their SCs in 3-5 years, despite fears of construction organisations reverting back to traditional methods due to economic downturn (refer sections 6.6 and 6.8).
- Despite claims in literature (Briscoe et al., 2002; Fearne and Fowler, 2006) with regard to the adversarial nature of construction organisations, most respondents of this research identified the CSF 'Positive attitude and approach to working relationships' as performing very well among their SC members (refer section 6.6.1).
- Construction professionals do expect most benefits achieved via SCM in non-construction industries within the construction industry, despite claims by Fernie and Thorpe (2007) of the construction industry being unique and not in a position to realise benefits of SCM as claimed in other industries (refer section 5.7).
- Two schools of thought with regard to the need for continuity of works in the construction industry emerged; one which suggests that continuity of works is essential to promote integration of SCs, and the other which suggests that collaborative ethos should allow integration of SCs even with regard to short-term projects.

8.4 Recommendations to the construction industry

The following recommendations can be derived for the construction industry, from this research. Construction organisations should focus on improving their SCs based on the 13 CSFs suggested via this research. The 13 CSFs identified in this research indicates the industry with regard to what is important when developing their SCs. Furthermore the scores for the 13 CSFs provide an idea about the importance of each CSF. Thus construction organisations can understand the most important CSFs when starting to develop their SCs, and continue to improve them over time with regard to all identified CSFs. Moreover, construction organisations can assess their level of integration based on the developed SCM framework, as performance measurement encourages further improvement. After all, this research identified that many construction professionals believe that benefits achieved in non-construction industries can be experienced in the construction industry as well via improved SCs.

The developed framework allows construction organisations to identify their level of integration based on different CSFs. The identification of an organisation's level of integration allows benchmarking, comparison of SC members and encourages performance related payments. Moreover, assessment is a precursor to further improvement. Construction organisations can use the SCM framework to understand further improvements needed, and/ or benchmark their SCs against Level 4 or any other level of the SCM framework they consider appropriate to their organisation. It should be noted that despite the size of organisation or the level of expertise in SCM of the user, he/ she will find the SCM framework easy to use. Most construction organisations can apply the developed framework to their organisations without assistance. The descriptions available for each CSF for the four levels of integration will allow organisations to understand their level of integration and thereby consider any improvements needed to move to higher levels of integration.

8.5 Limitations of research

The Delphi survey was limited to the construction industry of NI. Although many practices which influence SCM in the construction industry, such as culture, procurements methods, and approaches to dispute resolution are similar to Great Britain in NI, differences in regions are inevitable. Therefore it is possible that a similar Delphi survey conducted in England would have provided somewhat different responses which leads to slightly different descriptions in the framework. Moreover, the number of limited responses in the Delphi survey questions the ability to generalise results, particularly of the scores generated for the 13 CSFs. Furthermore, due to the low response rate, the results derived from the factor analysis will be very sensitive, and therefore a larger study in future may be necessary to verify the findings.

During the process of analytic induction of formulating the framework based on responses of the Delphi experts, some information may have been lost or adapted. The responses collected via the Delphi survey were checked for similarities and patterns manually. Thereafter, similar responses were compiled to form concise descriptions, for the inclusion in the framework. This process essentially leads to adaption of information, and sometimes loss of information. Furthermore, there is the possibility that, if carried out by another researcher, the transformation of information could be different. Thus, the subjectivity of the process questions the accuracy of the descriptions included in the framework. Furthermore, the list of 13 CSFs was generated based on previous literature and verified via the Delphi survey. However, the comprehensiveness of the list can be challenged, due to the possibility of some CSFs not yet being recorded in literature and possibility of not including some CSFs from available literature. Moreover, the verification of the list was via the Delphi survey, which has its own disadvantages as discussed earlier.

The questionnaire survey only generated 60 usable responses, where the target number of responses was 179. Thus it was not possible to conclude propositions or identify correlations with regard to different sub-sectors of the construction industry as expected. Furthermore, it questions the ability to generalise the results such as current and future levels of integration or ease or usefulness of applying the framework to the UK construction industry. Moreover, it should be remembered that due to University of Ulster being based in NI, a higher percentage of responses were received from NI. This also leads to results being somewhat biased towards the NI construction industry, questioning its applicability to the whole of UK. The respondents were also requested to use the framework for assessing their SCs prior to providing feedback on the framework. Hence the results on current and future levels of integration are provided on a framework which was not tested. Thus operationalising the framework alongside testing of the framework is a limitation of the research.

Since there are differences between early and late respondents to the e-survey, it is most likely that non-respondents to the e-survey are different to the average respondent of the e-survey. After all it is most likely that construction professionals who are more appreciative of SCM responded to this survey. They probably belong to organisations that are more enthusiastic of SCM principles. This would mean that results for current and future levels of integration are not representative of all the construction SCs in the UK. Furthermore, conclusions of propositions are biased towards more SCM enthusiastic organisations.

8.6 *Recommendations for further research*

The CSFs can be scored via a UK wide questionnaire survey, which will allow establishing a benchmark index which can be generalised to the whole of UK. Moreover, the incorporation of scores within the framework would lead to assessment being more comparable between SCs, and setting benchmarks more straightforward. Thus the industry could benefit from a more goal-oriented framework which helps improve SCs. Case studies can also be conducted among clients, consultants, contractors, etc. to gauge the applicability of the framework to different sub-sectors of the construction industry. This method would be more realistic than questionnaire surveys in the current climate of the UK. Furthermore, the in-depth understanding case studies provide, with regard to the differences of sub-sectors in the construction industry, will provide rich qualitative data which will help tailor the framework to suit different SC members.

Another questionnaire survey can be conducted, in a few years, in the UK to establish the framework's applicability the UK construction industry. A substantial number of responses may be achieved in future years, with economic improvement in the UK. This would allow generalisation of the tested framework and related results to the whole of UK. Case studies can also be conducted to elaborate the SCM framework, enhancing its applicability at the operational level. The in-depth insight case studies provide with regard to application of SCM in the construction industry will help understand the detailing needed to improve the framework which will help organisations understand how to improve SCs further. Since a more detailed framework might result in information overload, an IT interface could be utilised to maintain the simplicity, whilst adding richness to the framework.

Another Delphi survey, focusing the higher levels of integration, can be conducted in another few years to establish the need for a 5th level for the SCM framework. Since a substantial number of organisations are already in levels 3 and 4 of the framework, it becomes necessary to add further differentiation within these levels. Moreover, there is the possibility that in the future the construction industry advances its collaborative behaviour, which requires further levels to be added to the developed framework.

Further research can also help identify an optimum level of integration, which may not necessarily be the highest level of integration, for small construction organisations who may be dealing with short-term projects constantly. McLaren (2006) identified this phenomenon, where the highest level of integration available is not practical for some organisations. Hence in-depth case studies can help identify the optimum level of integration for different sub-sectors of the construction industry.

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Appendices

Pilot expert panel for the Delphi survey

Category of respondent	Designation	Years of relevant experience	Involved with SCs (based on their opinion)	Knowledge of SCM (based on section 1 of R1a questionnaire
Consultant	Managing Director	35	Yes	Satisfactory
Contractor	Development manager	18	Yes	Satisfactory
Sub-contractor	Civil engineer	7	Yes	Satisfactory
Supplier	Commercial manager	38	Yes	Satisfactory
Client	Senior professional technical officer	40	Yes	Satisfactory

The 31 respondents of the Delphi survey

Category of respondent	Designation	Years of relevant experience	Involved with SCs (based on their opinion)	Knowledge of SCM (based on section 1 of R1a questionnaire
Client	Senior manager	40	Yes	Satisfactory
Client	Project sponsor	9	Yes	Satisfactory
Client	Area operations manager	15	Yes	Satisfactory
Client	Procurement manager	22	Yes	Satisfactory
Client	Head of department	40	Yes	Satisfactory
Client	Assistant director	32	Yes	Satisfactory
Client	Chief QS	25	Yes	Satisfactory
Client	Manager	18	Yes	Satisfactory
Consultant	Managing Director	35	Yes	Satisfactory
Consultant	Director	27	Yes	Satisfactory
Consultant	Architectural director	33	Yes	Satisfactory
Consultant	Manager	19	Yes	Satisfactory
Consultant	Director	30	Yes	Satisfactory
Consultant	Director	34	Yes	Satisfactory
Consultant	Partner	10	Yes	Satisfactory
Consultant	Chartered QS	17	Yes	Satisfactory
Consultant	Chartered QS	12	Yes	Satisfactory
Contractor	Development manager	18	Yes	Satisfactory
Contractor	Commercial director	17	Yes	Satisfactory
Contractor	Managing director	28	Yes	Satisfactory

Appendix 1 – List of respondents for the Delphi survey (including pilot surveys)

Category of respondent	**Designation**	**Years of relevant experience**	**Involved with SCs (based on their opinion)**	**Knowledge of SCM (based on section 1 of R1a questionnaire**
Contractor	Estimating manager	20	Yes	Satisfactory
Contractor	PFI D&B manager	18	Yes	Satisfactory
Contractor	Managing director	22	Yes	Satisfactory
Contractor	Contracts manager	16	Yes	Satisfactory
Contractor	Environmental manager	19	Yes	Satisfactory
Supplier	Commercial manager	38	Yes	Satisfactory
Supplier	Civil engineer	7	Yes	Satisfactory
Supplier	Manager	10	Yes	Satisfactory
Supplier	Divisional director	37	Yes	Satisfactory
Supplier	Divisional manager	20	Yes	Satisfactory
Supplier	Manager	35	Yes	Satisfactory

Dear Sir/ Madam,

Survey on development of a model for integration of construction supply chains

Thank you for agreeing to participate in this pilot survey regarding construction supply chains. As explained over phone, this research aims to develop a model to measure the degree of integration of construction supply chains (CSCs). In this endeavour I hope to conduct a Delphi survey (an iterative process of consecutive questionnaire surveys) of 3 rounds as listed below (months indicated for each round are tentative).

Round 1 (January, 2010) – To prioritise critical success factors (CSFs) for integration of construction supply chains.
Round 2 (March, 2010) – To examine the linear progression of each of the CSFs, along the axis of integration, and establish scores for each degree of integration of CSFs.
Round 3 (May, 2010) – To discuss the usage of the framework, and any further improvements required to help construction firms assess and improve their supply chains.

As you are now a member of the expert panel setup for the pilot survey for this research, I would contact you before each Delphi round to check the clarity of questionnaire.

The questionnaire for Delphi - Round 1 (File name: R1) consists of 3 parts, as follows:

Page 1 – General questions
Page 2 – Assessment of factors leading towards integrated CSCs.
Page 3 – Assessment of factors expected from integrated CSCs.

Please answer above 3 parts, and respond to the pilot survey questionnaire (File name: Pilot_R1), also attached herewith.

I would like to receive both questionnaires by the 10th of December, 2009. If you have any queries with regard to this survey, please do not hesitate to contact me on 028 9036 8644, [redacted] or ss.gunasekera@ulster.ac.uk.

Anonymity of respondents will be maintained throughout this survey, and every attempt will be taken to annonymise data when results are published.

Thank you.

Yours sincerely

Sanwara Gunasekera
Room 1H06
The School of the Built Environment
University of Ulster at Jordanstown
BT37 0QB.

Pilot survey on Delphi (Round 1) questionnaire regarding integration of construction supply chains

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Name of respondent:

Designation of respondent:

Name of organisation:

How would you rate your expertise in the area of construction supply chain management (in relation to other professionals in your sector)?

Poor ☐ Satisfactory ☐ Good ☐ Very good ☐ Excellent ☐

In your opinion who are the key participants of a typical construction supply chain? Please list in the order of most important to least important.

How long did you take to fill in the questionnaire? What is your opinion regarding the length of the Delphi (Round 1) questionnaire?

What is your opinion regarding the clarity of questions and statements in the Delphi (Round 1) questionnaire?

What is your opinion regarding the Likert scale to measure the 'Degree of importance' of factors leading to integrated construction SCs?

What is your opinion regarding the Likert scale to measure the 'Degree of expectation' of benefits via integrated construction supply chains?

Please comment overleaf on any other factor(s) you think can be changed in the Delphi (Round 1) questionnaire to improve its survey response rates.

Dear Sir/Madam

Survey on development of a model for integration of construction supply chains

Thanks for agreeing to participate in this Delphi survey, which aims to verify a theoretical framework which I have proposed for construction supply chain management (SCM). SCM can be defined broadly as follows:

> "SCM is the integration of key business processes from end user through to original suppliers that provides products, services and information which add value for customers and other stakeholders." (Lambert and Cooper, 2000)

I have herewith attached the questionnaire for round 1 of the survey. Please fill in the information requested, and e-mail it to ss.gunasekera@ulster.ac.uk, preferably within two weeks. It is estimated that the attached questionnaire will take no more than 10 minutes to complete.

As explained during our telephone conversation, this survey will consist of approximately 3 rounds of questionnaires to achieve the following objectives.

Round 1 (January, 2010) – To prioritise critical success factors (CSFs) for integration of construction supply chains.

Round 2 (March, 2010) – To examine the linear progression of each of the CSFs, along the axis of integration, and establish scores for each degree of integration of CSFs.

Round 3 (May, 2010) – To discuss the usage of the framework, and any further improvements required to help construction firms assess and improve their supply chains.

I hope to receive responses from you within two weeks, for each of the three rounds. The tentative month for conducting each round is stated above. If you have any queries with regard to this survey, please do not hesitate to contact me on 028 9036 8644 or ss.gunasekera@ulster.ac.uk.

Anonymity of respondents will be maintained throughout this survey, and every attempt will be taken to annonymise data when results are published.

I thank you again for assisting in this research. I look forward to receiving the duly-filled questionnaire (herewith attached) on or before Wednesday, 20th of January, 2010.

Yours sincerely

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Survey on integration of construction supply chains (Delphi_Round 1)

Name of respondent:

Designation of respondent:

Name of organisation:

Nature of organisation:

Consultancy - Architecture ☐	Material supplier ☐	Plant supplier ☐
Consultancy- Engineering ☐	Contractor with turnover (TO) p.a.:	Subcontractor ☐
Consultancy- Quantity surveying ☐	TO > € 50 million ☐	Public-sector client ☐
Consultancy- Project Management ☐	TO ≤ € 50 million ☐	Private-sector client ☐

How would you rate your expertise in the area of construction supply chain management (in relation to other professionals in your sector)?

Poor ☐ Satisfactory ☐ Good ☐ Very good ☐ Excellent ☐

What does the concept 'supply chain integration' mean to you and your organisation? (in approximately 100 words)

Do you think it is beneficial for your organisation to be included in a well integrated supply chain? (in approximately 100 words)

In the following page you will find some factors identified, in literature, as crucial to supply chain integration in different industries. Please state the degree of importance of these factors to construction supply chains, according to your experience, using the scale given at the top of the next page.

If you think that some factors critical to integration of construction supply chains have been omitted in this list, please add them to the table and state their degree of importance using the scale given.

Likert scale for 'Degree of importance'

0	1	2	3	4	5
Not at all important	Slightly important	Moderately important	Important	Very important	Extremely important

Critical success factors <u>leading to</u> an integrated construction SC (supply chain)		Degree of importance					
		0	1	2	3	4	5
1.	Level of trust between SC members						
2.	Availability and use of IT for collaboration between SC members						
3.	Promoting engagement of all SC members at the client briefing stage						
4.	Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs						
5.	Procurement methods used to procure projects						
6.	Length of project duration or Continuity of work to sustain the SC						
7.	Extent of communication between SC members						
8.	Existence of a system to measure performance of SC members (i.e.KPIs)						
9.	Existence of a strategy for training and development of SC members						
10.	Existence of a protocol for conflict resolution among SC members						
11.	Degree of collaboration, between SC members, when making key decisions						
12.	Availability of a vision, mission, strategy, policy and procedures for management of SC						
13.	Positive attitude and approach to working relationships (i.e. win-win attitude and mutual relationships, rather than win-lose attitude and adversarial relationships)						
Please add any other factors you think should be included here, and state their degree of importance.							
14.							
15.							

Following are some factors identified, in literature, as expected from integrated supply chains in different industries. Please state the degree of expectation of these factors from construction supply chains, using the scale given below.

If you think that some benefits expected from construction supply chains have been omitted in this list, please add them to the table and state their degree of expectation using the scale given.

Likert scale for 'Degree of expectation'

0	1	2	3	4	5
Not at all expected	Slightly expected	Moderately expected	Expected	Very much expected	Extremely expected

	Competitive advantages <u>expected from</u> integrated construction supply chains	Degree of expectation
1.	Improved quality (and reduced defects) of construction output	
2.	Improved ability to deliver projects on time	
3.	Improved predictability of project budget	
4.	Better value for money to clients	
5.	Client satisfaction with regard to responsiveness and assurance of construction professionals	
6.	Improved employee satisfaction	
7.	Increased productivity on site	
8.	Promotion of sustainability	
9.	Reduced accidents at work	
10.	Increased turnover and profits	
11.	Reduced operational costs	
12.	Improved ability to deliver innovative solutions	
13.	Improved ability to deliver unique and customized solutions to clients	
Please add any other factors you think should be included here, and state their degree of expectation.		
14.		
15.		

Appendix 5 - Analysis of quantitative responses received in Delphi Round 1a

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	lower quartile	upper quartile	Mean	Quartile range
1	Level of trust between SC members	4	5	4.1935	-1
2	Availability and use of IT for collaboration between SC members	3	4	3.4516	-1
3	Promoting engagement of all SC members at the client briefing stage	2.5	4	3.2903	-1.5
4	Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs	4	5	4.2258	-1
5	Procurement methods used to procure projects	2	4	3.1667	-2
6	Length of project duration or Continuity of work to sustain the SC	3	4	3.2903	-1
7	Extent of communication between SC members	4	4.5	3.9677	-0.5
8	Existence of a system to measure performance of SC members (i.e.KPIs)	3	4	3.3548	-1
9	Existence of a strategy for training and development of SC members	2	4	2.9667	-2
10	Existence of a protocol for conflict resolution among SC members	3	4	3.3871	-1
11	Degree of collaboration, between SC members, when making key decisions	3	5	3.8710	-2
12	Availability of a vision, mission, strategy, policy and procedures for management of SC	3	4	3.4839	-1
13	Positive attitude and approach to working relationships	4	5	4.3548	-1
				47.0043	

Appendix 5

	Competitive advantages <u>expected from</u> integrated construction supply chains	lower quartile	upper quartile	Mean	Quartile range
1	Improved quality (and reduced defects) of construction output	3	4	3.7742	-1
2	Improved ability to deliver projects on time	4	5	4.0645	-1
3	Improved predictability of project budget	3.5	5	4.0968	-1.5
4	Better value for money to clients	3.5	4	3.9032	-0.5
5	Client satisfaction with regard to responsiveness and assurance of construction professionals	3	4	3.8710	-1
6	Improved employee satisfaction	2	3.5	2.9032	-1.5
7	Increased productivity on site	3	4	3.4839	-1
8	Promotion of sustainability	2	4	3.1613	-2
9	Reduced accidents at work	2	4	3.0645	-2
10	Increased turnover and profits	2.5	4	2.9677	-1.5
11	Reduced operational costs	3	4	3.1290	-1
12	Improved ability to deliver innovative solutions	3	4	3.6774	-1
13	Improved ability to deliver unique and customized solutions to clients	3	4	3.5161	-1

Appendix 6 - Analysis of qualitative responses received in Delphi Round 1a

		Cns 10	Con 6	Con 4	Client 2	client 8	client 3
	Critical success factors leading to an integrated construction SC (supply chain)						
4	Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs		Dedication of key relevant people to SCs				
5	Procurement methods used to procure projects				Use of NEC contracts		
7	Extent of communication between SC members	Outmoded information				Good personal relationships	
10	Existence of a protocol for conflict resolution among SC members				subcontracts should mirror the main contract, and allow for adjudication		
11	Degree of collaboration, between SC members, when making key decisions		Respect of each party that decisions they make may have an impact on other parties				
12	Availability of a vision, mission, strategy, policy and procedures for management of SC	Welcome change					Commitment of SC to achieving 'best value for money'
13	Positive attitude and approach to working relationships within SCs			Appreciation of SCM benefits		Good personal relationships	

Survey on integration of construction supply chains

Dear [redacted],

Many thanks for responding to Round 1 of this survey. Seventeen out of 26 factors/questions tested in Round 1 of this survey achieved consensus with regard to ‘degree of importance’ and ‘degree of expectation’. However, 9 factors remain to be retested. This is an opportunity for you to revise your scores for these 9 factors, in light of the overall group response.

We (Joe Gunning, George Heaney, Rodney McAdam and I) anticipate that this questionnaire will take less than 5 minutes to complete. I would like to receive your responses by Friday, the 2nd of April, 2010.

As a member of the ‘Pilot expert panel’ of this survey, in addition to completing the attached questionnaire it would be much appreciated if you let me know whether the questionnaire is clear with regard to the task, and/or if you suggest any improvements.

Thank you.

Yours sincerely,

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Survey on integration of construction supply chains (Round 2)

Name of respondent	**Name of organisation**	**Nature of organisation**
[redacted]	[redacted]	Large Contractor

17 out of 26 factors/questions tested in Round 1 of this survey achieved consensus with regard to 'degree of importance' and 'degree of expectation'. However, 9 factors remain to be retested. This is an opportunity for you to maintain or revise your scores for these 9 factors, in light of the overall group response.

Likert scale for 'Degree of importance'

0	1	2	3	4	5
Not at all important	Slightly important	Moderately important	Important	Very important	Extremely important

	Critical success factors leading to an integrated construction SC (supply chain)	Group score	Your previous score	Your revised score
1.	Promoting engagement of all SC members at the client briefing stage	3.2903	3	
2.	Procurement methods used to procure projects	3.1667	2	
3.	Existence of a strategy for training and development of SC members	2.9667	2	
4.	Degree of collaboration, between SC members, when making key decisions	3.8710	5	

Likert scale for 'Degree of expectation'

0	1	2	3	4	5
Not at all expected	Slightly expected	Moderately expected	Expected	Very much expected	Extremely expected

	Competitive advantages expected from integrated construction supply chains	Group score	Your previous score	Your revised score
1.	Improved predictability of project budget	4.0968	5	
2.	Improved employee satisfaction	2.9032	1	
3.	Promotion of sustainability	3.1613	2	
4.	Reduced accidents at work	3.0645	2	
5.	Increased turnover and profits	2.9677	0	

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	lower quartile	upper quartile	Mean	Quartile range
3	Promoting engagement of all SC members at the client briefing stage	2.5	3.5	2.8182	-1
5	Procurement methods used to procure projects	3	4	3.1818	-1
9	Existence of a strategy for training and development of SC members	2	3	2.8182	-1
11	Degree of collaboration, between SC members, when making key decisions	3	4	3.6364	-1

	Competitive advantages <u>expected from</u> integrated construction supply chains				
3	Improved predictability of project budget	4	4	4.0909	0
6	Improved employee satisfaction	2	4	3.0000	-2
8	Promotion of sustainability	3	4	3.1818	-1
9	Reduced accidents at work	2.5	3.5	2.7273	-1
10	Increased turnover and profits	3	4	3.2727	-1

Appendix 10 - Finalisation of scores for the 13 critical success factors

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	lower quartile	upper quartile	Mean	Quartile range	weighted avg
1	Level of trust between SC members	4	5	4.1935	-1	8.93%
2	Availability and use of IT for collaboration between SC members	3	4	3.4516	-1	7.35%
3	Promoting engagement of all SC members at the client briefing stage	2.5	4	3.2258	-1	6.87%
4	Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs	4	5	4.2258	-1	9.00%
5	Procurement methods used to procure projects	2.25	4	3.3000	-1	7.03%
6	Length of project duration or Continuity of work to sustain the SC	3	4	3.2903	-1	7.01%
7	Extent of communication between SC members	4	4.5	3.9677	-0.5	8.45%
8	Existence of a system to measure performance of SC members (i.e.KPIs)	3	4	3.3548	-1	7.15%
9	Existence of a strategy for training and development of SC members	2	4	3.0000	-1	6.39%
10	Existence of a protocol for conflict resolution among SC members	3	4	3.3871	-1	7.22%
11	Degree of collaboration, between SC members, when making key decisions	3	4	3.7097	-1	7.90%
12	Availability of a vision, mission, strategy, policy and procedures for management of SC	3	4	3.4839	-1	7.42%
13	Positive attitude and approach to working relationships	4	5	4.3548	-1	9.28%
				46.9452		100.00%

Rotated factor matrix from SPSS

	Factor				
	1	**2**	**3**	**4**	**5**
Existence of a system to measure performance of SC members (i.e.KPIs)	0.823				
Existence of a strategy for training and development of SC members	0.812	0.433			
Availability and use of IT for collaboration between SC members	0.640				
Existence of a protocol for conflict resolution among SC members	0.591				
Degree of collaboration, between SC members, when making key decisions		0.870			
Availability of a vision, mission, strategy, policy and procedures for management of SC		0.777			
Extent of communication between SC members		0.667			
Positive attitude and approach to working relationships		0.453		0.329	
Length of project duration or Continuity of work to sustain the SC			0.993		
Procurement methods used to procure projects	0.427		0.572	0.381	0.307
Support and commitment of leaders/ senior management of all SC member organisations towards integrated SCs			0.538	0.340	0.367
Level of trust between SC members				0.864	
Promoting engagement of all SC members at the client briefing stage	0.357	0.469			0.804

Extraction method: Maximum Likelihood

Rotation method: Varimax with Kaiser Normalisation

Survey on integration of construction supply chains (Delphi_Round 2)

There are 13 CSFs identified as leading towards integrated SCs in the table below. Please suggest an ultimate goal or a benchmark for each of these CSFs which construction organisations should strive to achieve.

	Critical success factors leading to an integrated construction SC (supply chain)	**Ultimate goal/ Suggested benchmark/ An example of a best-in-class**
1.	Level of trust between SC members	
2.	Availability and use of IT for collaboration between SC members	
3.	Promoting engagement of all SC members at the client briefing stage	
4.	Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs	
5.	Procurement methods used to procure projects	
6.	Length of project duration or Continuity of work to sustain the SC	
7.	Extent of communication between SC members	
8.	Existence of a system to measure performance of SC members (i.e.KPIs)	
9.	Existence of a strategy for training and development of SC members	
10.	Existence of a protocol for conflict resolution among SC members	
11.	Degree of collaboration, between	

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Ultimate goal/ Suggested benchmark/ An example of a best-in-class**
	SC members, when making key decisions	
12.	Availability of a vision, mission, strategy, policy and procedures for management of SC	
13.	Positive attitude and approach to working relationships (i.e. win-win attitude and mutual relationships, rather than win-lose attitude and adversarial relationships)	

How would you suggest that each of the CSFs be mapped across 5 levels
A typical SCM model (proposed for other industries) consists of 4-5 levels of integration (please see appendix 1 and 2). Please map suggested examples or benchmarks for each level identified in the table below (Level 1 being minimal SC integration and Level 5 being the highest level of integration). I would suggest that you use your suggested benchmarks in table 1 as the examples for Level 5 in this table.

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5 (Use if applicable)**
1.	Level of trust between SC members					
2.	Availability and use of IT for collaboration between SC members					
3.	Promoting engagement of all SC members at the client briefing stage					

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5 (Use if applicable)**
4.	Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs					
5.	Procurement methods used to procure projects					
6.	Length of project duration or Continuity of work to sustain the SC					
7.	Extent of communication between SC members					

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5 (Use if applicable)**
8.	Existence of a system to measure performance of SC members (i.e.KPIs)					
9.	Existence of a strategy for training and development of SC members					
10.	Existence of a protocol for conflict resolution among SC members					
11.	Degree of collaboration, between SC					

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5 (Use if applicable)**
	members, when making key decisions					
12.	Availability of a vision, mission, strategy, policy and procedures for management of SC					
13.	Positive attitude and approach to working relationships (i.e. win-win attitude and mutual relationships, rather than win-lose attitude and					

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5 (Use if applicable)**
	adversarial relationships)					

Survey on integration of construction supply chains (Round 2)

Hello again

This is Sanwara Gunasekera from University of Ulster, conducting a research with Dr.Joseph Gunning, Prof. George Heaney and Prof. Rodney McAdam.

Many thanks for responding to the Round 1 of this survey (conducted in February/ March, 2010). Round 1 allowed critical success factors (CSFs) leading to an integrated construction supply chain to be weighted and prioritized for incorporation in a SCM model.

This round will focus on mapping each of the CSFs identified in Round 1 along four levels of integration. The 4 levels can be described as follows:

Level A – Departments/Sections within the assessed construction organisation are not integrated/ collaborative **(Worst-case scenario).**
Level B - Departments/Sections within the assessed construction organisation are internally integrated, but not integrated with any external organisations.
Level C – In addition to internal organisational integration, there is some collaboration with few external organisations.
Level D – There is evidence of extensive internal and external organisational collaboration **(Best case scenario)**.

An example of CSFs being mapped along these 4 levels is shown below.

Critical success factors (CSFs)	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)
Promoting engagement of all SC members at the client briefing stage	*Minimal briefing of requirements – maybe over the telephone. SC is unaware of client briefing.*	*SC members are aware but have no access to client briefing.*	*SC members have access to but are not invited to contribute/respond to client briefing.*	*SC members are invited at an early stage to contribute to the formation of the client brief and understand the client requirements.*
Existence of a strategy for training and development of SC members	*No strategy for training and development.*	*Training and development plans for internally focused.*	*Sporadic training amongst specific individuals.*	*Good programme of regular and accountable training leading to commitments at all levels.*

It would be much appreciated if you could complete the 13 CSFs, as above, in the attached questionnaire and email it to ss.gunasekera@ulster.ac.uk on or before Friday, 2nd of July 2010.

It is anticipated that this questionnaire will take approx. 45 minutes to complete. Further the pilot survey revealed that respondents may need clarifications with regard to this questionnaire. Hence I will attempt to contact you sometime next week. Alternatively, you can call me on direct line number 028 9036 8644 or [redacted] for any clarifications.

Thank you.

Yours sincerely,

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Survey on integration of construction supply chains (Delphi_Round 2)

This survey intends to develop 4 progressive levels of supply chain integration, for 13 critical success factors. The 4 levels of integration can be understood as follows:

Level A – Departments/Sections within the assessed construction organisation are not integrated/ collaborative **(Worst-case scenario).**
Level B - Departments/Sections within the assessed construction organisation are integrated, but not integrated with any external organisations.
Level C – In addition to internal organisational integration, there is some collaboration with few external organisations.
Level D – There is evidence of extensive internal and external organisational collaboration **(Best case scenario)**.

Please note that the above levels are for guidance only. You are free to assume and suggest any other classification. You should answer the table below from the point-of-view of a single construction organisation that is intending to assess its supply chains.

Please suggest one or more examples for each of the 4 levels identified below, for the 13 critical success factors.

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)
1.	Positive attitude and approach to working relationships				
2.	Support and commitment of leaders/ senior management of all SC member organizations towards				

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)
	integrated SCs				
3.	Level of trust between SC members				
4.	Extent of communication between SC members				
5.	Degree of collaboration, between SC members, when making key decisions				
6.	Availability of a vision, mission, strategy, policy and procedures for management of SC				
7.	Availability and use of IT for collaboration between SC members				
8.	Existence of a protocol for conflict resolution among SC members				
9.	Existence of a system to measure performance of SC members (i.e.KPIs)				
10.	Minimum length of project duration or				

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)
	Continuity of work to sustain the SC				
11.	Procurement methods used to procure projects				
12.	Promoting engagement of all SC members at the client briefing stage				
13.	Existence of a strategy for training and development of SC members				

1. Positive attitude and approach to working relationships - Level A (Minimal Integration)

Category	Response/ Transcript	Extract	Abstract reference number
Contractor	Minimal integration because of minimal understanding	Minimal understanding of collaboration.	1
Consultant	No agreement or prioritisation of objectives within the firm	No agreement of (project) objectives.	4
Contractor	No real desire from any party to create a working relationship.	No real desire for a working relationship.	2
Client	Not relevant, as there is very minimal or none collaboration	Minimal collaboration	1
Contractor	Understanding of partnering arrangements, more “contract” focussed than “partner oriented”	More “contract” focussed than “partner oriented”	3
Contractor	Contractor does not interact with the supply chain	Minimal interaction with SC members	2
Client	Main Contractor and Client are located separately on site and conditions of contract ensure that parties have little opportunity to work together in a positive manner.	Separate site locations for project members. Use of non-collaborative conditions of contract.	5 3
Client	Drawings and specifications passed within organisation but no verbal communication of special requirements timescales	No verbal communications of project requirements/ objectives.	2, 4
Consultant	Negative attitude to SC integration	Negative attitude towards collaboration.	1
Client	SC totally unaware of Clients desire for a positive attitude and approach to working relationships	Unaware of need for working relationships.	2
Client	Nothing inplace to facilitate relationship building	No facilitation of relationship building.	2
Contractor	Employees do not support each others’ actions and there is a lack of communication.	Lack of good working relationships and interaction.	2
Consultant	No direct contact between SC members and therefore no development of working relationships	Lack of interaction and development of working relationships.	2

Abstract:

1. Minimal understanding of need for collaboration. (3)

2. There is not much interaction between SC members and no facilitation of working relationships. (7)
3. SC members are more ‘contract focused’ than ‘partner oriented’. (2)
4. There is no agreement of project objectives. (2)
5. Will probably have separate site locations for project participants. (1)

1. Positive attitude and approach to working relationships - Level B (Internal Integration)

Category	Response/ Transcript	Extract	Abstract reference number
Contractor	Good understanding of the objectives of SCM but only amongst limited persons.	Some understand the need for collaboration.	1
Consultant	Internal objectives only ie exclude third party gains	(Project) objectives are set excluding external organisations.	3
Contractor	Appreciation of need to create positive working relationship but not followed through.	Appreciates need for collaboration, but not practiced.	1
Client	Relevant, but not necessarily at all levels of the organisation; critical only to employees directly communicating with other Departments/Sections of the organisation	There is collaboration at some levels of an organisation.	2
Contractor	SC members are integrated within internal departments and understand partnering principals while working internally but may not trust external partners enough to work in a similar transparent manner.	Some internal collaboration, but do not trust external partners to work in a transparent manner.	2
Contractor	Contractor will form internal meetings to discuss supply chain performances without any external participation	Meetings organised without external participation.	3
Client	Main Contractor and Client are located separately on site. Progress meetings do not include entire supply chain	Separate locations for project participants. Progress meetings do not include all SC members.	4 3
Client	S C Departmental heads or team leaders discuss timescales, special requirements	Collaboration at senior managerial levels.	2
Consultant	Acceptance of the importance of SC integration within the organisation	Accepts importance of collaboration.	1
Client	SC aware of Clients desire for a positive attitude and approach to	Aware of need for collaboration.	1

Category	Response/ Transcript	Extract	Abstract reference number
	working relationships		
Client	Minimal – only internal relationships important	Focuses mostly on relationships within a single firm.	2
Contractor	Good working relationships and communication within the company.	Collaboration present within the organisation.	2
Consultant	Individual SC member organisations develop good internal working relationships but there is limited contact, perhaps at Director or manager level only, between the separate organisations	Collaboration at senior managerial level.	2

Abstract:

1. Appreciates the need for collaboration. (4)
2. Some collaboration apparent, especially at senior managerial level and/or within a firm. (6)
3. Project meetings and objectives may be set excluding external organisations. (3)
4. May still have separate site locations for project participants from different firms. (1)

1. Positive attitude and approach to working relationships - Level C (Some External Collaboration)

Category	Response/ Transcript	Extract	Abstract reference number
Contractor	Key persons in participating organisations with common attitude – but not at less senior levels	Key/ Senior personnel of supply chain collaborate.	1
Consultant	Insufficient strategic approach to selecting best potential business partners	Lacks strategic approach for collaboration.	5
Contractor	Some discussion between parties regarding creating working relationship but no commitment.	Discussions about collaboration, but not committed.	3
Client	Highly essential within the organisation as each individual representing organisation to external organisations will reflect the climate within the organisation	All levels attempt to demonstrate appreciation of collaboration to external organisations.	4
Contractor	Lasting relationships have developed with key external supply chain members (i.e. M&E)	Collaborative relationships have developed with key SC members.	1
Contractor	Contractor will meet with supply chain prior to placing of order and negotiation meetings only after winning job.	Collaboration occurs after winning tender.	2
Client	Main Contractor and Client are located together on site Occasionally progress meetings do include entire supply chain	Main Contractor and Client are located together on site. Occasionally progress meetings do include entire supply chain.	6 2
Client	Contractor meets with selected suppliers	Collaborative relationships have developed with key SC members.	1
Consultant	Positive attitude to collaboration with long established SC members	Appreciates collaborative relationships with key SC members.	1
Client	SC aware of Clients desire for a positive attitude and approach to working relationships but given no opportunity to contribute suggestions	Appreciates need for collaboration, but not sure how to implement.	3

Category	**Response/ Transcript**	**Extract**	**Abstract reference number**
	as to how this can be achieved		
Client	Relationships are expanding to some supply chain	Begins to build relationships with some SC members.	2
Contractor	Suppliers that a working relationship have been established with over the years.	Collaborative relationships with key SC members.	1
Consultant	Some of the major SC members are included in the project and client meetings or team building events and therefore good working relationships with some of the SC members are developed.	Collaborative relationships with key SC members.	1

Abstract:

1. Collaborative relationships have developed with key SC members. (6)
2. If not, will be starting to build relationships with selected SC members, at least after tender stage. (3)
3. Some may be uncertain about how to engage in a collaborative relationship. (2)
4. However, the firm would demonstrate to external organisations that they appreciate collaborative working. (1)
5. Will probably lack of a strategic approach to collaboration. (1)
6. Key SC members might share same site offices. (1)

1. Positive attitude and approach to working relationships - Level D (Extensive External Collaboration)

Category	**Response/ Transcript**	**Extract**	**Abstract reference number**
Contractor	Clear objectives by persons across all organisations and at all personnel levels.	Clear objectives for collaboration for all SC members.	4
Consultant	Corporate goals and processes are aligned across the business and externally with business partners	Corporate goals are aligned with SC members.	4
Contractor	Formal committee established and MoU in place for creating positive working relationships.	Formal committee & MoU for creating positive working relationships.	5
Client	Highly essential within the organisation as each individual representing organisation to external organisations will reflect the climate within the organisation (same as level C)	All levels attempt to demonstrate appreciation of collaboration to external organisations.	2
Contractor	Clear understanding of SC partners risk profile and all parties actively work to reduce exposure to partners risk and promote collaborative working and terms through the entire supply chain.	All SC members actively work towards reducing exposure of risk of partners, and promote collaborative working and terms through the entire SC.	1
Contractor	Contractor will actively meet and discuss project with supply chain before tender and also throughout project in performance and progress meetings	Involvement of SC members throughout the project.	3
Client	Main Contractor and Client are located together on site and conditions of contract ensure that parties work together in a positive manner. All progress meetings do include entire supply chain	Key SC members may share site offices. Conditions of Contracts support partnering. All SC members get involved in all project meetings.	6 5 3
Client	Contractor holds detailed precontract and award meetings with all SC members inviting them	All SC members are involved to some level in project meetings.	3

Category	Response/ Transcript	Extract	Abstract reference number
	to comment on specification / drawings etc. Contractor then holds meeting with design team to discuss issues raised.		
Consultant	Positivity to embracing SC integration in all aspects of the business	Collaboration encouraged in every aspect of business.	2
Client	SC aware of Clients desire for a positive attitude and approach to working relationships and given full opportunity to contribute suggestions as to how this can be achieved	Appreciates collaboration in every aspect of business.	2
Client	All SC involved relationships now key Creating interdependability within the SC	The SC is established with signs of interdependability among SC members.	1
Contractor	Suppliers that are assess before given the opportunity to supply and relationships have subsequently developed.	Established SC.	1
Consultant	All members of the SC are included, as early as possible, at project team meetings and team building events	Meetings involve all SC members as practicable as possible.	3

Abstract:

1. The SC is now established, and there are signs of interdependability among SC members. (3)
2. Collaboration is encouraged in every aspect of business. (3)
3. SC members are involved throughout the project. (4)
4. Objectives for collaboration may be set, and corporate goals may be aligned to achieve these objectives. (2)
5. Conditions of Contract and MoUs support partnering/ collaborative working. (2)
6. Key SC members may share site offices. (1)

Abstraction of the developed SCM framework for the construction industry

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)
1.	Positive attitude and approach to working relationships	1. Minimal understanding of need for collaboration. (3) 2. There is not much interaction between SC members and no facilitation of working relationships. (7) 3. SC members are more ‘contract focused’ than ‘partner oriented’. (2) 4. There is no agreement of project objectives. (2) 5. Will probably have separate site locations for project participants. (1)	1. Appreciates the need for collaboration. (4) 2. Some collaboration apparent, especially at senior managerial level and/or within a firm. (6) 3. Project meetings and objectives may be set excluding external organisations. (3) 4. May still have separate site locations for project participants from different firms. (1)	1. Collaborative relationships have developed with key SC members. (6) 2. If not, will be starting to build relationships with selected SC members, at least after tender stage. (3) 3. Some may be uncertain about how to engage in a collaborative relationship. (2) 4. However, the firm would demonstrate to external organisations that they appreciate collaborative working. (1) 5. Will probably lack of a strategic approach to collaboration. (1) 6. Key SC members might share same site offices. (1)	1. The SC is now established, and there are signs of interdependability among SC members. (3) 2. Collaboration is encouraged in every aspect of business. (3) 3. SC members are involved throughout the project. (4) 4. Objectives for collaboration may be set, and corporate goals may be aligned to achieve these objectives. (2) 5. Conditions of Contract and MoUs support partnering/ collaborative working. (2) 6. Key SC members may share site offices. (1)

	Critical success factors **leading to** an integrated construction SC (supply chain)	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)
2.	Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs	1. There is almost no support by senior management to collaborate. (8) 2. They display selfish behaviour and possibly are not aware of benefits of collaboration. (6)	1. There is limited support by key personnel to collaborate. (4) 2. Promotion of collaboration will be limited to internal departments/ sections. (8)	1. Senior management support collaboration.(6) 2. They are now committed to extending collaborative practices to a few selected external organisations. (6) 3. Training may be provided to promote trust and communication with external organisations. (3)	1. Senior management support collaboration of all SC members. (6) 2. This support may be for the long-term or for the duration of project. (2) 3. There will be documentation and procedures to support collaboration and/ or collaboration may be embedded in culture at this stage. (9)
3.	Level of trust between SC members	1. Nil to limited trust present. (8) 2. Lack of trust may be due to poor relationships, communication and/or understanding of SCM. (3) 3. Such companies will practice closed book accounting, operating within silos, blame culture and possible hostility and competition between SC members. (4)	1. There is limited trust. (2) 2. Trust might be one-way. (2) 3. There is trust within a single organisation. (4) 4. Ineffective external relationships. (3) 5. Strict procedures when communicating externally. (1) 6. Lack of trust may be due to poor understanding of SCM. (1) 7. Such companies will	1. Some trust between established SC members. (6) 2. Good level of trust between some SC members. (2) 3. Good working relationships with some SC members. (2) 4. Trust leads to open book accounting. (1) 5. Open book accounting not practiced. (1)	1. A high level of trust between SC members. (4) 2. Trust exists among all SC members. (3) 3. Trust built up through long term partnering and frequent communication. (1) 4. Trust built up through regular meetings and team building events. 5. Open-book accounting practiced. (3) 6. Trust apparent due to open discussions and

	Critical success factors **leading to** an integrated construction SC (supply chain)	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)
			practice closed book accounting. (1)		honest advice. (1) 7. Prompt payments to all SC members. (1) 8. Good working relationships with all SC members from early stages of project. (3))
4.	Extent of communication between SC members	1. No or little communication. (7) 2. Communication limited within departments. (2) 3. Communication limited to contractual requirements. (1) 4. No formal communication. (2) 5. Communication limited to telephone calls. (2)	1. No or little communication among SC members. (4) 2. Good communication within an organisation. (2) 3. Limited communication with external organisations. (3) 4. There is regular formal communication via email. (2) 5. There is formal and informal communication. (3)	1. Some communication between key SC members. (2) 2. Good communication with key SC members. (3) 3. Minimal communication with external organisations. (1) 4. No or little communication (among SC members). (1) 5. No communication plan for SC. (1) 6. Some formal communication between SC members. (3) 7. Regular formal and informal communication with SC members. (2)	1. Frequent communication. (1) 2. Effective and efficient information transfer along SC. (1) 3. Good communication with all SC members from an early stage of project. (1) 4. Constructive communication occurs between SC members. (4) 5. Extensive communication between SC members. (2) 6. Formal communication system accessible by all SC members. (6)

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)
5.	Degree of collaboration, between SC members, when making key decisions	1. No collaboration between SC members when making key decisions. (7) 2. Collaboration limited to contractual requirements. (1) 3. No active collaboration between SC members. (2) 4. Poor collaboration. (1)	1. There is good collaboration internally within a single organisation. (6) 2. However there is limited collaboration with external organisations. (6) 3. No active collaboration between SC members. (2)	There is overlap in definitions. a) Good collaboration b) Some collaboration c) Collaboration with all SC members. d) Collaboration with selected SC members. e) Structured meetings organised regularly.	1. Collaboration with all SC members through regular meetings. (2) 2. Collaboration between all SC members is supported by communication systems. (3) 3. Proactive collaboration with SC members. (2) 4. Good collaboration between all SC members. (4)
6.	Availability of a vision, mission, strategy, policy and procedures for management of SC	1. None in existence. (11) 2. If in existence not communicated correctly. (1)	1. Some documentation in existence. (9) 2. but not communicated to SC members. (6) 3. Vision etc. is not aligned with rest of the SC members. (1) 4. Being implemented by senior management. (1) 5. Some awareness of vision, etc. (1)	1. Formal policy. (3) 2. Vision etc. may include references to key SC members. (2) 3. In place and communicated to SC informally. (1) 4. In place. (5) 5. Disseminated but not fully explained, understood or followed. (1) 6. Communicated to most. (2) 7. Continuous development through	1. Formal documentation in place. (3) 2. Detailed documentation in place. (2) 3. Documentation encompasses entire SC. (2) 4. Entire SC has contributed to the documentation. (2) 5. Entire SC supports vision... (4) 6. Formal implementation. (3)

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	Level A (Minimal Integration)	Level B (Internal Integration)	Level C (Some external collaboration)	Level D (Extensive external collaboration)
				external audits. (1) 8. Limited implementation. (3) 9. Not implemented. (1)	
7.	Availability and use of IT for collaboration between SC members	1. No IT systems in place. (4) 2. Inadequate IT systems in place. (6) 3. SC members have limited IT skills. (1) 4. Emails/ fax available. (2)	1. Internal IT systems established. (8) 2. SC members have good IT skills. (2) 3. No access for external SC members. (5) 4. Limited access for external SC members due to incompatibility of software. (1) 5. Insignificant use of IT between SC members. (1)	1. Internal IT system established. (2) 2. Internet-based IT system. (2) 3. Accessible by all SC members. (1) 4. Accessible by selected SC members. (2) 5. Limited access for some SC members. (6) 6. IT compatibility is adhoc. (2) 7. SC members have good IT skills. (1) 8. Email system that encompasses SC members is in place. (2)	6. Extensive IT collaboration. (6) 7. Access available to SC members. (6) 8. IT training provided for all SC members. (1) 9. IT strategy agreed across SC. (1) 10. SC members have good IT skills. (1) 11. Mandatory use of IT for collaboration. (2) 12. All SC members have compatible IT systems. (1)
8.	Existence of a protocol for conflict resolution among SC members	1. No protocol in place. (9) 2. Limited to contract mechanisms. (2) 3. Protocol in place but not fully implemented. (1) 4. Source of conflict is removed from job, with	1. No protocol in place. (2) 2. Some protocols in place. (2) 3. Protocols in place internally. (4) 4. Protocol in place. (3) 5. Different interpretation of protocol between SC	1. Some protocols in place. (3) 2. Protocols in place among key SC members. (3) 3. Protocols in place among SC members. (3) 4. Protocols formally	1. Formal protocol for entire SC. (10) 2. All SC members involved in the development of

	Critical success factors **leading to** an integrated construction SC (supply chain)	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)
		no attempts for resolution. (1)	members. (1) 6. Protocol not formally communicated to SC members. (1) 7. Protocols applied through contract mechanisms. (1) 8. Source of conflict given verbal warning regarding possible removal. (1)	communicated to SC members. (1) 5. External advisors appointed for conflict resolution. (1) 6. SC members encouraged to use conflict resolution. (1) 7. Different interpretation of protocol between SC members. (1)	protocol. (1) 3. SC charter promotes avoiding conflict. (1) 4. Regular meetings to address issues and avoid conflict. (1)
9.	Existence of a system to measure performance of SC members (i.e.KPIs)	1. No system in place for performance measurement. (12) 2. Some performance measurement at department level. (1)	1. No system in place for performance measurement. (1) 2. A performance measurement system exists (but rarely used). (2) 3. Some use of performance measurement. (4) 4. Performance measurement focuses on a single organisation. (5)	1. Systems in place for collaborative performance measurement (for the entire SC). (5) 2. Systems in place for collaborative performance measurement among key SC members. (4) 3. Limited collaborative performance measurement. (2) 4. Performance measurement focuses on a single organisation. (1) 5. Performance measurement systems are inconsistent across	1. Systems in place for collaborative performance measurement. (10) 2. Performance measurement systems are consistent and aligned across the SC. (1) 3. Performance measurement system is comprehensive. (2) 4. Performance measurement is a formal procedure and is contractual. (1) 5. SC members proactively encouraged to use performance measurement. (2)

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	Level A (Minimal Integration)	Level B (Internal Integration)	Level C (Some external collaboration)	Level D (Extensive external collaboration)
				the SC. (1) 6. Some SC members unsure of how to measure performance. (1) 7. SC members proactively encouraged to use performance measurement. (1)	6. All SC members understand the process of performance measurement. (2) 7. SC members are engaged in the development of the performance measurement system. (2)
10	Minimum length of project duration or Continuity of work to sustain the SC	1. No commitment to SC for continuity of work. (9) 2. An effective SC is created only if the project has a substantially long duration. (1) 3. Very short duration of projects only allow minimal integration of projects. (1)	1. No commitment to external organisations for continuity of work. (4) 2. Short duration of projects only allow some integration. (2) 3. An effective SC is created only if the project has a somewhat long duration. (1) 4. SC member is willing to collaborate with other potential projects. (1) 5. Considers collaboration if several projects are carried out. (1) 6. Some indication of future projects and potential collaboration.	1. Indication of further work based on good performance. (1) 2. Informal commitment to key SC members regarding possible continuity of work. (2) 3. An effective SC is created even if the project has a somewhat short duration. (1) 4. Some successful collaboration with long-term projects (or repeat projects). (3) 5. SC member is willing to collaborate with other potential projects. (1)	1. Continuity of work and long term relationships with SC members. (4) 2. Formal contractual commitment to continuity of work. (2) 3. SC members are well integrated even for a single or short-term project. (4) 4. SC members actively encouraged to bring opportunities/projects to collaborate in future. (1)

	Critical success factors <u>leading to</u> an integrated construction SC (supply chain)	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)
			(1)		
11	Procurement methods used to procure projects	1. Procurement is driven through price alone. (5) 2. Traditional procurement methods used. (4) 3. Choice of procurement methods is adhoc. (4) 4. Procurement methods do not mention/encourage SCM. (1)	1. Procurement is driven through price alone. (1) 2. Procurement is driven mostly through price, with few other considerations. (3) 3. A mixture of traditional and new procurement methods. (1) 4. SC members open to new procurement methods but will need training. (1) 5. Procurement methods do not encourage SCM, although mentioned. (1) 6. Procurement methods are selected for individual gain rather than of project. (2) 7. The focal organisation is committed to creating long-term partnerships. (1) 8. A regular group of SC members are invited to tender. (1)	1. Price and quality driven procurement methods used. (2) 2. A mixture of traditional and new procurement methods. (1) 3. Repeat projects are common with established SC members. (1) 4. Commitment to key SC members for long-term partnerships. (2) 5. Procurement methods detail the use of an integrated SC, and actively encourage their use. (1) 6. The focal organisation creates a SC strategy and informs other SC members. (1)	1. Price and quality driven procurement methods used. (2) 2. Procurement methods detail and enforce the use of an integrated SC. (1) 3. SC demonstrates good understanding of all types of procurement methods. (1) 4. The procurement strategy is developed by all SC members to suit project. (2) 5. Commitment to key SC members for long-term partnerships. (2) 6. Use of procurement methods which promote partnering, long-term collaboration, PRP and open-book accounting. (2)
12	Promoting engagement of all	1. Minimal/informal briefing. (6)	1. No involvement of SC at briefing stage. (3)	1. SC members are provided with client	1. All SC members are involved in developing

	Critical success factors leading to an integrated construction SC (supply chain)	Level A (Minimal Integration)	Level B (Internal Integration)	Level C (Some external collaboration)	Level D (Extensive external collaboration)
	SC members at the client briefing stage	2. No involvement of SC at briefing stage. (10)	2. SC members are aware but have no access to client briefing. (4) 3. Informal client briefing with key SC members. (4)	brief but have no input to the development of the brief. (6) 2. Client briefing involves key SC members. (4) 3. SC members' opinions are sought at the client briefing stage. (2)	the client brief. (11)
13	Existence of a strategy for training and development of SC members	1. No strategy for training and development. (11) 2. Minimal of training and development. (2)	1. No strategy for training and development. (1) 2. Limited in-house training. (2) 3. Training and development is focused within a single organisation. (8) 4. A strategy for training and development of SC members exists. (2)	1. Training and development is focused within a single organisation. (2) 2. Sporadic training offered to some SC members. (5) 3. Training and development offered to key SC members. (3) 4. A strategy for training and development of SC members exists and adherence to strategy is encouraged. (1)	1. Regular and accountable training to all SC members. (9) 2. Training and development programmes are designed and implemented with SC. (2) 3. A strategy for training and development of SC members exists and adherence to strategy is made compulsory. (1)

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
1	**Positive attitude and approach to working relationships**	Minimal understanding of need for collaboration. There is not much interaction between SC members and no facilitation of working relationships. SC members are more 'contract focused' than 'partner oriented'. Will probably have separate site locations for project participants and no agreement of project objectives.	Appreciates the need for collaboration. Some collaboration apparent, especially at senior managerial level and/or within a firm. Project meetings and objectives may be set excluding external organisations. May still have separate site locations for project participants from different firms.	Collaborative relationships have developed with key SC members. If not, will be starting to build relationships with selected SC members, at least after tender stage. Some may be uncertain about how to engage in a collaborative relationship. However, the firm would demonstrate to external organisations that they appreciate collaborative working. Will probably lack of a strategic approach to collaboration. Key SC members might share same site offices.	The SC is now established, and there are signs of interdependability among SC members. Collaboration is encouraged in every aspect of business. SC members are involved throughout the project. Objectives for collaboration may be set, and corporate goals may be aligned to achieve these objectives. Conditions of Contract and MoUs support partnering/ collaborative working. Key SC members may share site offices.
2	**Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs**	There is almost no support by senior management to collaborate. They display selfish behaviour and possibly are not aware of benefits of collaboration.	There is limited support by key personnel to collaborate. Promotion of collaboration will be limited to internal departments/ sections.	Senior management support collaboration. They are now committed to extending collaborative practices to a few selected external organisations. Training may be provided to promote trust and communication with external organisations.	Senior management support collaboration, of all SC members. This support may be for the long-term or for the duration of project. There will be documentation and procedures to support collaboration and/ or collaboration may be embedded in culture at this stage.

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
3	**Level of trust between SC members**	Nil to limited trust present among people. Lack of trust may be due to poor relationships, communication and/or understanding of SCM. Such companies will practice closed book accounting, operate within silos, observe blame culture and there is hostility and competition between SC members.	There is limited trust. Trust might be one-way. Trust may be within a single organisation. There will be ineffective external relationships and strict procedures when communicating externally. Lack of trust may be due to poor understanding of SCM. Such companies will practice closed book accounting.	Some trust between selected SC members. There will be good working relationships with these SC members.	A high level of trust exists among all SC members at this stage. Trust exists among all SC members. Trust is built-up through long term partnering, frequent communication, regular meetings and team building events. Trust is apparent due to open discussions, honest advice, open book accounting, good working relationships from early stages of a project and prompt payments to all SC members.
4	**Extent of communication between SC members**	There is no or little communication. Any communications will be limited within departments and to contractual requirements. Communication will be via telephone and not through formal methods.	There is formal and informal communication at this stage. Communication within an organisation will be good, although there will still be minimal communication with SC members.	There is good communication with selected SC members. Communication will be regular and will take place both formally and informally.	There is good communication with all SC members from an early stage of project. Communication at this stage is frequent, efficient, effective, constructive and extensive. The formal communication system will be accessible by all SC members.
5	**Degree of collaboration, between SC members, when making key decisions**	There is minimal collaboration. Any collaboration will be limited to contractual requirements.	There is good collaboration internally within a single organisation. However, there is limited collaboration with external organisations. No active collaboration between SC members.	There is good collaboration among selected SC members. Structured meetings may be organized regularly.	There is good and proactive collaboration with SC members. Collaboration with all SC members is supported via communication systems and regular meetings.

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
6	**Availability of a vision, mission, strategy, policy and procedures for management of SC**	A vision, mission, strategy, policy or procedures for management of SC does not exist.	Some documentation on vision, etc. exists but is not communicated to SC members. Therefore vision etc. will not be aligned with the rest of the SC members.	There is a formal policy on vision, etc. and they may include references to key SC members. This might be communicated to SC informally, but may not be fully explained, understood or followed.	There will be formal and detailed documentation in place, encompassing the entire SC. The entire SC will contribute to and support the vision, mission, etc.
7	**Availability and use of IT for collaboration between SC members**	No or inadequate IT systems in place. Usage of IT will be limited to emails/fax. SC members have limited IT skills.	Internal IT systems are established at this stage. However the software will be incompatible with external SC members. Hence there will be limited access for and insignificant use of IT between SC members.	There will be established IT systems internally with limited access for some SC members. The IT systems will be internet-based, promoting accessibility. However IT compatibility with SC members could be adhoc. SC members, at this stage, will have good IT skills.	There will be extensive IT collaboration, where IT training is provided and access allowed for all SC members. The IT strategy will be agreed across the SC and IT usage for collaboration will be made compulsory. All SC members will have good IT skills and compatible IT systems.
8	**Existence of a protocol for conflict resolution among SC members**	No protocol in place for conflict resolution among SC members; conflict resolution is limited to contract mechanisms.	Some protocols in place for conflict resolution but not formally communicated to SC members. There may be different interpretation of protocols.	Protocols in place among key SC members and is formally communicated along the SC. There still may be different interpretation of protocols. SC members are encouraged to use conflict resolution and external advisors may be appointed, if necessary.	There is a formal protocol for the entire SC and all SC members get involved in developing the protocol. Regular meetings are held to address issues and avoid conflict.

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
9	**Existence of a system to measure performance of SC members (i.e.KPIs)**	There is no system in place for performance measurement.	There is some use of performance measurement. At this stage performance measurement may focus only on a single organisation.	There is limited collaborative performance measurement. Performance measurement systems are inconsistent across the SC and some SC members may be unsure of how to measure performance.	There are systems in place for collaborative performance measurement. These systems are comprehensive, consistent, aligned across the SC, contractual and formal. SC members are involved in the development of this system, understand the process of measurement and are proactively encouraged to use performance measurement.
10	**Procurement methods used to procure projects**	Traditional procurement methods are used, and is driven through price alone. Procurement methods are chosen in an ad hoc manner and SCM is not mentioned or encouraged.	Procurement is mostly price driven and SCM (although may be mentioned) is not encouraged. SC members will be open to new procurement methods. Selection of procurement methods would be for individual gain rather than of project. The focal organisation could be committed to creating long-term partnerships and a regular group of SC members invited to tender.	Procurement methods are price and quality driven, and there is commitment to key SC members for long-term partnerships. Repeat projects are common with established SC members. The focal organisation may create a SC strategy and inform SC members, and the procurement methods may detail the use of an integrated SC and actively encourage their use.	Procurement methods promote partnering, long-term collaboration, PRP and open-book accounting. The SC demonstrates good understanding of all types of procurement methods. The procurement strategy is developed by all SC members to suit project, and there is commitment to key SC members for long-term partnerships.

		Level 1 (Minimal Integration)	Level 2 (Internal Integration)	Level 3 (Some external collaboration)	Level 4 (Extensive external collaboration)
11	**Length of project duration or Continuity of work to sustain the SC**	No commitment to SC for continuity of work.	There might still be no commitment to external organisations for continuity of work. However, if several projects are carried out, collaboration might be considered and future projects indicated to SC members.	At this stage there will be some successful collaboration with long-term projects and repeat projects. There will be informal commitment to key SC members regarding possible continuity of work. Indication of further work will be based on good performance.	There is a formal contractual commitment to continuity of work and long-term relationships with SC members. SC members are well-integrated even for a single or short-term project and are actively encouraged to bring opportunities/ projects to collaborate in future.
12	**Promoting engagement of all SC members at the client briefing stage**	There is minimal involvement of SC at client briefing stage. At best, there might be some informal briefing.	SC members will be aware of client briefing stage, but have no access to documentation. There will be informal briefing with key SC members.	SC members are provided with client brief. They will not input to the development of the brief although their opinions may be sought and they are somewhat involved at this stage.	All SC members are involved in developing the client brief.
13	**Existence of a strategy for training and development of SC members**	There is no strategy for training and development and minimal training provided to the SC and internally.	A strategy for training and development of SC members exists. However, training and development is focused within a single organisation.	A strategy for training and development of SC members exists and adherence to the strategy is encouraged. Sporadic training may be offered to some SC members.	A strategy for training and development of SC members exists and adherence to strategy is made compulsory. There will be regular and accountable training provided to all SC members. These programmes are designed and implemented with the involvement of the SC.

Survey on integration of construction supply chains (Delphi_Round 2b)

This survey intends to validate 4 progressive levels of supply chain integration, for 13 critical success factors (CSFs). The 4 levels of integration can be understood as follows:

Level A – Departments/Sections within the assessed construction organisation are not integrated/ collaborative **(Worst-case scenario).**
Level B - Departments/Sections within the assessed construction organisation are internally integrated, but not integrated with any external organisations.
Level C – In addition to internal organisational integration, there is some collaboration with few external organisations.
Level D – There is evidence of extensive internal and external organisational collaboration **(Best case scenario)**.

Please note that the above levels are for guidance only. You are free to assume and suggest any other classification.

Please turn over.

	CSFs **leading to** an integrated construction SC	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)	**Please use this column to state any further comments that you may have.**
1.	Positive attitude and approach to working relationships	Minimal understanding of need for collaboration. There is not much interaction between SC members and no facilitation of working relationships. SC members are more 'contract focused' than 'partner oriented'. Will probably have separate site locations for project participants and no agreement of project objectives.	Appreciates the need for collaboration. Some collaboration apparent, especially at senior managerial level and/or within a firm. Project meetings and objectives may be set excluding external organisations. May still have separate site locations for project participants from different firms.	Collaborative relationships have developed with key SC members. If not, will be starting to build relationships with selected SC members, at least after tender stage. Some may be uncertain about how to engage in a collaborative relationship. However, the firm would demonstrate to external organisations that they appreciate collaborative working. Will probably lack of a strategic approach to collaboration. Key SC members might share same site offices.	The SC is now established, and there are signs of interdependability among SC members. Collaboration is encouraged in every aspect of business. SC members are involved throughout the project. Objectives for collaboration may be set, and corporate goals may be aligned to achieve these objectives. Conditions of Contract and MoUs support partnering/ collaborative working. Key SC members may share site offices.	

	CSFs leading to an integrated construction SC	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)	**Pl use this column to state any comments that you may have.**
2.	Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs	There is almost no support by senior management to collaborate. They display selfish behaviour and possibly are not aware of benefits of collaboration.	There is limited support by key personnel to collaborate. Promotion of collaboration will be limited to internal departments/ sections.	Senior management support collaboration. They are now committed to extending collaborative practices to a few selected external organisations. Training may be provided to promote trust and communication with external organisations.	Senior management support collaboration, of all SC members. This support may be for the long-term or for the duration of project. There will be documentation and procedures to support collaboration and/ or collaboration may be embedded in culture at this stage.	
3.	Level of trust between SC members	Nil to limited trust present among people. Lack of trust may be due to poor relationships, communication and/or understanding of SCM. Such companies will practice closed book accounting, operate within silos, observe blame culture and there is hostility and competition between SC members.	There is limited trust. Trust might be one-way. Trust may be within a single organisation. There will be ineffective external relationships and strict procedures when communicating externally. Lack of trust may be due to poor understanding of SCM. Such companies will practice closed book accounting.	Some trust between selected SC members. There will be good working relationships with these SC members.	A high level of trust exists among all SC members at this stage.	

	CSFs leading to an integrated construction SC	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)	**Pl use this column to state any comments that you may have.**
4.	Extent of communicatio n between SC members	There is no or little communication. Any communications will be limited within departments and to contractual requirements. Communication will be via telephone and not through formal methods.	There is formal and informal communication at this stage. Communication within an organisation will be good, although there will still be minimal communication with SC members.	There is good communication with selected SC members. Communication will be regular and will take place both formally and informally.	There is good communication with all SC members from an early stage of project. Communication at this stage is frequent, efficient, effective, constructive and extensive. The formal communication system will be accessible by all SC members.	
5.	Degree of collaboration, between SC members, when making key decisions	There is minimal collaboration. Any collaboration will be limited to contractual requirements.	There is good collaboration internally within a single organisation. However, there is limited collaboration with external organisations. No active collaboration between SC members.	There is good collaboration among selected SC members. Structured meetings may be organized regularly.	There is good and proactive collaboration with SC members. Collaboration with all SC members is supported via communication systems and regular meetings.	

	CSFs leading to an integrated construction SC	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)	**Pl use this column to state any comments that you may have.**
6.	Availability of a vision, mission, strategy, policy and procedures for management of SC	A vision, mission, strategy, policy or procedures for management of SC does not exist.	Some documentation on vision, etc. exists but is not communicated to SC members. Therefore vision etc. will not be aligned with the rest of the SC members.	There is a formal policy on vision, etc. and they may include references to key SC members. This might be communicated to SC informally, but may not be fully explained, understood or followed.	There will be formal and detailed documentation in place, encompassing the entire SC. The entire SC will contribute to and support the vision, mission, etc.	
7.	Availability and use of IT for collaboration between SC members	No or inadequate IT systems in place. Usage of IT will be limited to emails/fax. SC members have limited IT skills.	Internal IT systems are established at this stage. However the software will be incompatible with external SC members. Hence there will be limited access for and insignificant use of IT between SC members.	There will be established IT systems internally with limited access for some SC members. The IT systems will be internet-based, promoting accessibility. However IT compatibility with SC members could be adhoc. SC members, at this stage, will have good IT skills.	There will be extensive IT collaboration, where IT training is provided and access allowed for all SC members. The IT strategy will be agreed across the SC and IT usage for collaboration will be made compulsory. All SC members will have good IT skills and compatible IT systems.	

	CSFs leading to an integrated construction SC	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)	**Pl use this column to state any comments that you may have.**
8.	Existence of a protocol for conflict resolution among SC members	No protocol in place for conflict resolution among SC members; conflict resolution is limited to contract mechanisms.	Some protocols in place for conflict resolution but not formally communicated to SC members. There may be different interpretation of protocols.	(Some) Protocols in place among (key) SC members and is formally communicated along the SC. There still may be different interpretation of protocols. SC members are encouraged to use conflict resolution and external advisors may be appointed, if necessary.	There is a formal protocol for entire SC and all SC members get involved in developing the protocol. Regular meetings are held to address issues and avoid conflict.	
9.	Existence of a system to measure performance of SC members (i.e.KPIs)	There is no system in place for performance measurement.	There is some use of performance measurement. At this stage performance measurement may focus only on a single organisation.	There is limited collaborative performance measurement. Performance measurement systems are inconsistent across the SC and some SC members may be unsure of how to measure performance.	There are systems in place for collaborative performance measurement. These systems are comprehensive, consistent, aligned across the SC, contractual and formal. SC members are involved in the development of this system, understand the process of measurement and are proactively encouraged to use performance measurement.	

	CSFs leading to an integrated construction SC	Level A (Minimal Integration)	Level B (Internal Integration)	Level C (Some external collaboration)	Level D (Extensive external collaboration)	Pl use this column to state any comments that you may have.
10.	Procurement methods used to procure projects	Traditional procurement methods are used, and is driven through price alone. Procurement methods are chosen in and adhoc manner and SCM is not mentioned or encouraged.	Procurement is mostly price driven and SCM (although may be mentioned) is not encouraged. SC members will be open to new procurement methods. Selection of procurement methods would be for individual gain rather than of project. The focal organisation could be committed to creating long-term partnerships and a regular group of SC members invited to tender.	Procurement methods are price and quality driven, and there is commitment to key SC members for long-term partnerships. Repeat projects are common with established SC members. The focal organisation may create a SC strategy and inform SC members, and the procurement methods may detail the use of an integrated SC and actively encourage their use.	Procurement methods promote partnering, long-term collaboration, PRP and open-book accounting. The SC demonstrates good understanding of all types of procurement methods. The procurement strategy is developed by all SC members to suit project, and there is commitment to key SC members for long-term partnerships.	
11.	Minimum length of project duration or Continuity of work to sustain the SC	No commitment to SC for continuity of work.	There might still be no commitment to external organisations for continuity of work. However, if several projects are carried out, collaboration might be considered and future projects indicated to SC members.	At this stage there will be some successful collaboration with long-term projects and repeat projects. There will be informal commitment to key SC members regarding possible continuity of work. Indication of further work will be based on good performance.	There is a formal contractual commitment to continuity of work and long-term relationships with SC members. SC members are well-integrated even for a single or short-term project and are actively encouraged to bring opportunities/projects to collaborate in future.	

	CSFs leading to an integrated construction SC	**Level A** (Minimal Integration)	**Level B** (Internal Integration)	**Level C** (Some external collaboration)	**Level D** (Extensive external collaboration)	**Pl use this column to state any comments that you may have.**
12.	Promoting engagement of all SC members at the client briefing stage	There is minimal involvement of SC at client briefing stage. At best, there might be some informal briefing.	SC members will be aware of client briefing stage, but have no access to documentation. There will be informal briefing with key SC members.	SC members are provided with client brief. They will not input to the development of the brief although their opinions may be sought and they are somewhat involved at this stage.	All SC members are involved in developing the client brief.	
13.	Existence of a strategy for training and development of SC members	There is no strategy for training and development and minimal training provided to the SC and internally.	A strategy for training and development of SC members exists. However, training and development is focused within a single organisation.	A strategy for training and development of SC members exists and adherence to the strategy is encouraged. Sporadic training may be offered to some SC members.	A strategy for training and development of SC members exists and adherence to strategy is made compulsory. There will be regular and accountable training provided to all SC members. These programmes are designed and implemented with the involvement of the SC.	

Survey on a model for assessing integration of construction supply chains in the UK

(Note: This is a PDF version of the questionnaire distributed via an online survey tool. Therefore the formatting was quite different to the questionnaire below.)

Section A: General information

Page 1

1) **Your designation:**

* 2) **Your level of involvement with construction supply chains:**

- Highly involved
- Moderately involved
- Involved on an ad-hoc basis
- Not much involved

* 3) **Your level of expertise in construction supply chain management (in your opinion):**

- Poor
- Satisfactory
- Good
- Very good
- Excellent

4) **Your organisation's turnover per annum:**

- More than 50 million Euros
- 10 - 50 million Euros
- Less than 10 million Euros

5) **Number of employees in your organisation:**

- 250 or more
- Less than 250
- Less than 50
- Less than 10

6) **Where is your office based?**

- England
- Wales
- Northern Ireland
- Scotland
- Republic of Ireland

* **7) The type of organisation you work for:**

☐ Client (Public sector)	☐ Client (Private sector)	☐ Consultancy (Architecture)	☐ Consultancy (Civil & structural eng)
☐ Consultancy (M & E)	☐ Consultancy (QS)	☐ Consultancy (Project management)	☐ Main contractor
☐ Trade subcontractor	☐ Specialist subcontractor	☐ Plant supplier	☐ Material supplier

Section B: Assessment of the SCM model

You will need a printout of the PDF document (SCM model for the CI) attached to the email to complete section B.

* **8) Assess the current level of integration of most projects that you are involved with in your organisation (based on the SCM model attached to the email) by selecting the appropriate level of integration for each of the 13 factors listed below.**

	Level 1	Level 2	Level 3	Level 4	NA/Don't know
1) Positive attitude and approach to working relationships	☐	☐	☐	☐	☐
2) Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs	☐	☐	☐	☐	☐
3) Level of trust between SC members	☐	☐	☐	☐	☐
4) Extent of communication between SC members	☐	☐	☐	☐	☐
5) Degree of collaboration, between SC members, when making key decisions	☐	☐	☐	☐	☐
6) Availability of a vision, mission, strategy, policy and procedures for management of SC	☐	☐	☐	☐	☐
7) Availability and use of IT for collaboration between SC members	☐	☐	☐	☐	☐
8) Existence of a protocol for conflict resolution among SC members	☐	☐	☐	☐	☐
9) Existence of a system to measure performance of SC members (i.e.KPIs)	☐	☐	☐	☐	☐
10) Minimum length of project duration or Continuity of work to sustain the SC	☐	☐	☐	☐	☐
11) Procurement methods used to procure projects	☐	☐	☐	☐	☐
12) Promoting engagement of all SC members at the client briefing stage	☐	☐	☐	☐	☐
13) Existence of a strategy for training and development of SC members	☐	☐	☐	☐	☐

Comments:

Section B continued

* 9) **Please let us know the future (say in 3-5 years) level of integration of most projects in your organisation (anticipated, in your opinion) based on the SCM model attached to the email.**

	Level 1	Level 2	Level 3	Level 4	NA/Don't know
1) Positive attitude and approach to working relationships					
2) Support and commitment of leaders/ senior management of all SC member organizations towards integrated SCs					
3) Level of trust between SC members					
4) Extent of communication between SC members					
5) Degree of collaboration, between SC members, when making key decisions					
6) Availability of a vision, mission, strategy, policy and procedures for management of SC					
7) Availability and use of IT for collaboration between SC members					
8) Existence of a protocol for conflict resolution among SC members					
9) Existence of a system to measure performance of SC members (i.e.KPIs)					
10) Minimum length of project duration or Continuity of work to sustain the SC					
11) Procurement methods used to procure projects					
12) Promoting engagement of all SC members at the client briefing stage					
13) Existence of a strategy for training and development of SC members					

Comments:

Section C: Your feedback on the SCM model

* **10) How easy or difficult is the SCM model to understand and use?**

- Extremely easy
- Moderately easy
- Neutral
- Somewhat difficult
- Extremely difficult

* **11) Do you find the model useful when trying to gauge a project's current level of integration?**

- Very useful
- Somewhat useful
- Not at all useful

Any comments on further improvements?

12) Does this model give you an indication as to how to improve and move onto the next level of integration?

- Yes, the model is very helpful in understanding how to move onto the next level.
- The model is somewhat useful in understanding how to move onto the next level.
- Although I can identify the level we strive to be in the future, I do not find the model sufficiently descriptive as to how to move to that level.
- No, I do not see the next level that we are aspring to be in this model.
- Not applicable, as my organisation does not intend to further improve.

Comments:

13) How many levels of integration do you think is ideal for a SCM model applicable to the construction industry?

- Can't say
- 3
- 4

- [ ] 5
- [ ] 6
- [ ] Other, please specify:

14) Are there any other comments you would like to make?